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CORALLINE ALGAE FROM THE EOCENE ATASCADERO LIMESTONE

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ABSTRACT—The upper Eocene Atascadero limestone of northwestern Peru locally contains abundant well-preserved coralline algae. Thirteen species are described of which six are new. They include representatives of the genera *Archaeolithothamnion, Lithothamnion, Lithophyllum, Mesophyllum* and *Lithoporella.*

INTRODUCTION

THIS study is based on a small collection of limestone specimens collected by Benton Stone and sent to the Colorado School of Mines Museum through the kindness of W. E. Wallis, both of the International Petroleum Company.

The specimens are from an outcrop of the Atascadero limestone, a facies equivalent to the upper Eocene Tabara formation. It was obtained along the Las Cruces-Atascadero road a few kilometers south of Atascadero, Department of Piura, N.W. Peru. This locality is the type for all new species described. The limestone is a brownish gray organic limestone. Algal debris comprises from 15 to 35 percent of the rock in the specimens studied. In addition there are numerous Foraminifera both large and small, ostracods, fragments of shells of mollusks, echinoid spines, and Bryozoa, all in a gray matrix of fine calcium-carbonate paste.

Repository.—The specimens described here are deposited in the Johnson Collection at the Colorado School of Mines.

SYSTEMATIC DESCRIPTIONS

The algal material consists of small pellets, broken pieces of branches, and thin crusts coating large Foraminifera and other fossil fragments. Most of the material is beautifully preserved and an unusually large percentage show fruits.

Genus ARCHAEOLITHOTHAMNION (Rothpletz) Foslie

Tissue composed of rectangular cells arranged in transverse rows. The hypothallus, always basal, consists of horizontal rows of cells. The perithallus usually shows a neat rectilinear cell pattern. Branches are composed entirely of perithallus. Sporangia arranged in concentric rows in the tissue. They are not grouped in conceptacles.

ARCHAEOLITHOTHAMNION LUGEONI Pfender
Plate 62, figs. 1, 4

Archaeolithothamnion lugeoni PFENDER, J., 1926, p. 321.
Archaeolithothamnion lugeoni LEMOINE, 1928, p. 94.
Archaeolithothamnion lugeoni RAMA RAO and PIA, 1936, p. 35.
Archaeolithothamnion lugeoni LEMOINE, 1939, p. 52.

Nodular masses 2.5 to 8.0 mm. across with rounded protruberances but not true branches, composed of a number of superimposed thalli. Hypothallus thin, of curved loosely packed rows of irregularly sized

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cells 0.015–0.030 mm. long, and 0.007–0.010 (12) mm. wide. Perithallus tissue of regular rows of rectangular cells 0.012–0.015 (17) mm. long and 0.008–0.012 mm. wide. Sporangia oval, abundant in fairly regular rows. They measure 0.055–0.085 mm. high and 0.035–0.045 mm. in diameter.

Discussion.—The structure, measurements, and growth habits perfectly fit this species. To date it has been reported from beds ranging in age from Upper Cretaceous (Danian) to lower Oligocene. It is abundant in the Eocene of Spain and Algeria.

The species is represented in our collection by seven specimens. Several of them are sections through large nodules.

Type.—Homoeotype, slide 1281. Johnson Collection, Colorado School of Mines.

Genus LITHOTHAMNION (Philippi)

Representatives of this genus are rather scarce in the collection studied. The majority are encrusting forms, although one highly branching form is present.

LITHOTHAMNION LIMAENSUM Johnson and Tafur, n. sp.
Plate 64, fig. 4

Crustose; thallus consisting of a thin hypothallus and a well-developed perithallus. Hypothallus consisting of curved rows of cells which measure 0.007–0.012 mm. long and 0.008–0.010 mm. wide. Perithallus consists of regularly arranged rows of rectangular cells 0.010–0.015 mm. long and 0.009–0.012 mm. wide. Conceptacle large, 0.580 mm. in diameter and 0.150 mm. high.

Discussion.—Resembles *L. concretum* Howe from the Oligocene of the West Indies but differs in growth habit and in having smaller conceptacles.

Type.—Holotype, slide 1285. Johnson Collection, Colorado School of Mines.

LITHOTHAMNION FAURAI Lemoine
Plate 62, fig. 5

L. faurai LEMOINE, 1928, p. 97, fig. 8.
L. faurai LEMOINE, 1939, p. 74, figs. 36, 37.

A strongly branching form. Tissue of branches shows growth zones. Cells in well-defined vertical rows. Cells vary considerably in length, even adjoining cells in a row. Sizes range from 0.009–0.023 mm. long and 0.009–0.013 mm. wide. Conceptacle measurements listed below:

Specimen 1	0.370×0.125 mm.	to	0.190×0.090
2	0.223×0.124		0.205×0.140
3	0.310×0.180		0.225×0.165

Discussion.—The material studied consists entirely of fragments of branches. In appearance, growth habit, and dimensions they closely fit Lemoine's descriptions based on material from the Eocene of France and Spain, except that the maximum cell length is slightly less in the Peruvian specimens.

Type.—Homoeotype, slide 1289a. Johnson Collection, Colorado School of Mines.

LITHOTHAMNION cf. L. CONCRETUM Howe

Several pieces of a crustose form which has a fair hypothallus and a well-developed perithallus occur. Hypothallus cells measure 0.012–0.018 mm. by 0.008–0.013 mm. The perithallus cells are 0.009–0.014 mm. long and 0.007–0.012 mm. wide. No conceptacles observed.

In growth habit and cell dimensions these fit the description of *L. concretum* Howe described from the Oligocene of the West Indies, but without conceptacles it is impossible to say definitely that they belong to that species.

Type.—Homoeotype, slide 1340. Johnson Collection, Colorado School of Mines.

LITHOTHAMNION WALLISIUM Johnson and Tafur, n. sp.
Plate 62, fig. 3

Crustose; hypothallus moderately developed consisting of curved irregular rows of rounded to nearly rectangular cells, which measure 0.011–0.016 mm. long and 0.008–0.011 mm. wide. Perithallus shows numerous irregular growth zones. Cells arranged in fairly regular vertical rows. Cells vary in size, ranging from 0.009–0.019 mm. long and 0.009–0.015 mm. wide. Conceptacles wide and flat, 0.250–0.500 mm. in diameter, and 0.116–0.130 mm. high.

Discussion.—This suggests *L. isthmi* Howe from the Oligocene of Panama in cell dimension and conceptacles but differs in the character of the hypothallus which is strongly coaxial in *L. isthmi* but consists of only moderately curved cell rows in *L. wallisium.*

Type.—Holotype, slide 1355. Johnson Collection, Colorado School of Mines.

Genus MESOPHYLLUM Lemoine 1928

Characterized by a clearly stratified, zonate branch tissue similar to the genus *Lithophyllum* and conceptacles with multiple openings similar to the genus *Lithothamnion*. Usually the branches consist entirely or almost entirely of medullary hypothallus with little or no marginal perithallus which is usually well developed on a typical *Lithophyllum*. Growth zones are usually more pronounced and the conceptacles are often larger in proportion to the mass of the tissue than in either *Lithophyllum* or *Lithothamnion*.

MESOPHYLLUM ATASCADERUM Johnson and Tafur, n. sp.
Plate 64, fig. 3

A small branching form with short stubby branches. Tissue strongly zoned. Each growth zone lenticular or crescent-shaped and usually contains four to seven rows of cells. Longitudinal partitions between the cell rows more pronounced than the transverse. Cells rectangular, measuring 0.012–0.025 mm. long and 0.09–0.016 mm. wide (average 0.020×0.012 mm.). Conceptacles oval, and rather high. They measure 0.208–0.212 mm. in diameter, and 0.134×0.142 mm. high on one specimen, and 0.278×0.134 mm. on another. There are suggestions of mutiple apertures in the roof of the conceptacles.

Discussion.—The cell dimensions of this form are within the range of *M. vaughanii* described by Howe (1918, p. 6) from the Oligocene of Panama, but the conceptacles of *M. atascaderum* are much smaller and its tissue does not show the alternation of rows of long and short cells mentioned by Howe. Named for the Peruvian town close to the type locality.

Type.—Holotype slide 1362. Johnson Collection, Colorado School of Mines.

MESOPHYLLUM PUERANUM Johnson and Tafur, n. sp.
Plate 63, fig. 4

Forms a basal crust from which develop long relatively slender branches. Basal hypothallus thin and poorly developed. Branches composed of slender lenticular growth zones each containing 5 to 12 layers of rectangular cells. Cells 0.018–0.029 mm.×0.012–0.021 mm. (average 0.022 ×0.015 mm.). Conceptacles show considerable size range as indicated below:

0.345×0.150 mm.
0.355×0.120 mm.
0.395×0.185 mm.
0.607×0.225 mm.
0.290×0.118 mm.
0.375×0.145 mm.
0.395×0.120 mm.

0.290–0.607 mm.×0.120–0.225 mm.

Discussion.—This species differs considerably in cell dimension and conceptacle size from all previously described Eocene and Oligocene species of *Mesophyllum*. Named for the Peruvian province containing the type locality.

Type.—Holotype, slide 1361. Johnson collection, Colorado School of Mines.

MESOPHYLLUM PERUVIANUM Johnson and Tafur, n. sp.
Plate 63, fig. 2

A form with short, slender branches. Tissue consists mainly of medullary hypothallus with distinct lenticular growth zones. Cells rectangular, measuring 0.009—0.019 mm. ×0.009–0.015 mm. Conceptacles large and prominent as compared with the mass of the tissue, measuring 0.200–0.500 mm. in diameter and 0.100–0.160 mm. high. There are a number of apertures piercing the roof of the conceptacle.

Discussion.—This species closely resembles *M. vaughanii* Howe, except in growth habit. *M. vaughanii* develops thick crusts with coarse anastomosing branches. *M. peruvianum* is represented in our collection by five specimens, all fragments of round, rather slender branches. The observed conceptacles also are much smaller in diameter than those of *M. vaughanii*. It differs from *M. atascaderum* in having slightly smaller cells, smaller and proportionately higher conceptacles, and in developing more slender branches.

Type.—Holotype, slide 1363. Johnson Collection, Colorado School of Mines.

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LITHOPHYLLUM SIERRA-BLANCAE Howe
Plate 64, fig. 1

Lithophyllum sierra-blancae HOWE, 1934, Geol. Soc. America, Bull., vol. 45, p. 514, pl. 56.

Thallus mammillated or slightly branching. A section through one of the mammillae or a short stubby branch shows the tissue to consist of a well defined medullary hypothallus and a marginal perithallus. Hypothallus consists of thin arched zones each containing five to ten rows of cells. Cells in well-defined transverse rows and fairly defined longitudinal rows. Cells rectangular. In upper row of each zone they decrease in size from center to top of a margin zone. There is also a slight decrease in height of cell rows from the base. They measure 0.013–0.022 mm. high, and 0.008–0.011 mm. wide (average 0.016–0.010 mm.). Perithallus consists of thin slightly irregular zones, each built of short tangential rows of cells. Cells square to rectangular, measuring 0.009–0.016 mm. high (average 0.0116) and 0.008–0.013 mm. wide (average 0.010). Conceptacles unknown.

Discussion.—Our infertile fragments fit the description and illustration given by Howe.

Type.—Homoeotype, slide 1282. Johnson Collection, Colorado School of Mines.

LITHOPHYLLUM INCAENSUM Johnson and Tafur, n. sp.
Plate 63, fig. 1

A nodular form which develops short stubby bifurcating branches. Tissue shows strong growth zones. Hypothallus poorly developed, consisting of short curving rows of irregular cells. Perithallus forms most of the tissue. It consists of rectangular cells 0.019–0.032 mm. long and 0.016–0.024 mm. wide, arranged in rows. Along the axes of the branches the longitudinal partitions between cell rows are more strongly developed than the transverse, and there is a suggestion of a radial structure. Along margins of the branches, a rectilinear pattern is suggested with transverse and longitudinal partitions about equally developed.

Conceptacles numerous, round to rectangular with rounded corners, unusually short and high. Sizes range 0.320–0.550 mm. wide (diameter) and 0.300–0.400 mm. high. A single opening is suggested but is not clearly shown on the large section of a nearly complete colony.

Discussion.—*L. incaensum* suggests *L. zonatum* J. & F. from the Eocene of Florida in having large cells and strong growth zones, but differs in cell dimension and growth habit.

Type.—Holotype, slide 1283a. Johnson Collection, Colorado School of Mines.

LITHOPHYLLUM sp. A.
Plate 63, fig. 3

Encrusting; thallus thin with both a hypothallus and a perithallus. Hypothallus consists of curving and sometimes contorted rows of cells. The cells are rounded and irregular at base, becoming rectangular at top. They measure 0.016–0.022 mm. long and 0.010–0.013 mm. wide. The perithallus consists of layers of rectangular cells with well-defined horizontal and vertical partitions. Cells measure 0.012–0.020 mm. long and 0.008–0.013 mm. wide. Often the cells in the upper layer are shorter than those in the middle layers. Conceptacles very small, bean-shaped in vertical section, abundant, measuring 0.039–0.082 mm. wide and 0.022–0.038 mm. high. A single roof

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EXPLANATION OF PLATE 62

FIG. 1—*Archaeolithothamnion lugeoni* Pfender, Homoeotype (slide 1281) ×40. Section through a nodular mass showing tissue and rows of sporangia. (p. 537)

2—*Lithoporella melobesioides* Foslie. Figured specimen (slide 1282) ×75 showing typical thalles. (p. 541)

3—*Lithothamnion wallisium* Johnson and Tafur, n. sp. Holotype (slide 1355) ×100. Shows conceptacles, perithallus. (p. 538)

4—*Archaeolithothamnion lugeoni* Pfender. Homoeotype (slide 1289) ×75, showing detail of tissue and sporangia. (p. 537)

5—*Lithothamnion faurai* Lemoine. Homoeotype (slide 1289a) ×100, giving detail of tissue and conceptacles. (p. 538)

1

2

3

4

5

Johnson and Tafur, Eocene Algae from Peru

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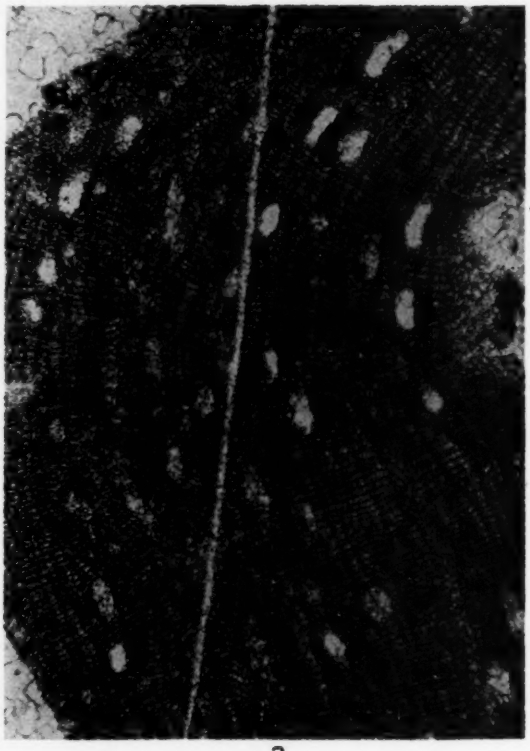
2



3

4

Johnson and Tafur, Eocene Algae from Peru

aperture is suggested but is not clearly shown.

Figured specimen.—Slide 1362. Johnson Collection, Colorado School of Mines.

LITHOPHYLLUM sp. B.
Plate 64, fig. 2

Thallus probably forming a branching or mammillated crust. Tissue shows growth zones composed of regular rows of rounded rectangular cells measuring 0.010–0.18 mm. long and 0.008–0.012 mm. wide. Horizontal partitions between cells thin and often indistinct. Conceptacle measured approximately 0.300 mm. in diameter and 0.150 mm. high.

Discussion.—Recognized in only one slide, the section is probably oblique, so data are considered too uncertain to give a specific name.

Figured specimen.—Slide 1283a. Johnson Collection, Colorado School of Mines.

Genus LITHOPORELLA Foslie

This genus shows the simplest structure of any of the Melobesieae. It also develops the largest cells and conceptacles.

A number of names have been applied to the genus. Madame Lemoine uses the name *Melobesia*, but most recent writers follow Foslie's use of *Lithoporella*.

The collection contains numerous specimens belonging to this genus. Mr. Tafur took a great interest in them and carefully studied every piece he could find. He measured hundreds of cells.

LITHOPORELLA (MELOBESIA) MELOBESIOIDES Foslie
Plate 62, fig. 2; plate 64, fig. 1

Lithoporella (*Mastophora*) *melobesioides* Foslie (Weber van Bosse and Foslie, 1904, pp. 73–77, figs. 30–32).
Melobesia (*Lithoporella*) *melobesioides* Foslie (Lemoine, 1939, pp. 108–110, figs. 78, 79).
Lithoporella melobesioides (Foslie) Foslie (Lignac-Grutterink, 1943, pp. 292–293, pl. 2, fig. 8).
Lithoporella (*Melobesia*) *melobesioides* J. & F., 1949, p. 196, pl. 37, figs. 4–5; and pl. 39, fig. 2.
Lithoporella (*Melobesia*) *melobesioides* J. & F., 1950, p. 18, pl. 8, fig. A.

Thallus thin, often less than 0.1 mm. thick, growing attached to other calcareous algae, Foraminifera, and other objects. In many cases they apparently started attached, then grew free.

Normally each thallus is formed of a single layer of cells, although sometimes, especially around conceptacles and at points where new thalles bud off, there is a local thickening of the tissue, and it may consist of several rows of smaller cells (plate 62, fig. 2). The cells are rectangular and are larger than in most genera of *Melobesia*. They show a great range in size in a single specimen as the cell layers swell and taper. The following table shows the measurements obtained from a number of specimens. Several thousand cells were measured. The average given in the last column is the mathematical average of all the cells in the row, not the mean between the extremes.

With such variation in cell size it is impossible to separate species unless there are differences in the conceptacles. Consequently, these are all considered to belong to one species which fits the description of the modern *L. melobesioides* Foslie. No conceptacles were observed.

Discussion.—This form was very common. Practically every slide contained at least one example. In some cases a number of thalles grew superimposed one upon another.

Type.—Homoeotypes, slides 1280, 1282, 1289, 1355, 1360. Johnson Collection, Colorado School of Mines.

EXPLANATION OF PLATE 63

FIG. *1*—*Lithophyllum incaensum* Johnson and Tafur, n. sp. Holotype (slide 1283a) ×25. A section through a mass showing pronounced growth zones, character of tissue, and conceptacles. (p. 540)

2—*Mesophyllum peruvianum* Johnson and Tafur, n. sp. Holotype (slide 1363) ×75. Shows detail of tissue and conceptacles. (p. 539)

3—*Lithophyllum* sp. *A*. Figured specimen (slide 1362) ×100. A section of the tissue with many spaces formerly occupied by conceptacles. (p. 540)

4—*Mesophyllum pueranum* Johnson and Tafur, n. sp. Holotype (slide 1361) ×100. Section of a branch showing tissue with growth zones and conceptacles. (p. 539)

(Plate 64 and its description will be found on page 548)

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Slide number	Length (mm.)	Width (mm.)	Average (mm.)
1280 row a	0.036–0.039	0.014–0.017	0.038×0.016
b	0.045–0.047	0.010–0.016	0.046×0.015
c	0.045–0.050	0.014–0.023	0.048×0.017
d	0.040–0.046	0.013–0.017	0.043×0.015
e	0.022–0.040	0.007–0.010	0.027×0.085
f	0.025–0.030	0.007–0.010	0.027×0.087
g	0.048–0.049	0.012–0.018	0.048×0.0155
h	0.046–0.047	0.012–0.016	0.046×0.0145
i	0.032–0.039	0.011–0.016	0.033×0.014
j	0.042–0.045	0.011–0.015	0.044×0.013
k	0.033–0.034	0.011–0.018	0.033×0.014
l	0.028–0.035	0.011–0.017	0.031×0.014
m	0.055–0.056	0.012–0.020	0.055×0.0155
n	0.065–0.065	0.016–0.021	0.065×0.018
o	0.050–0.052	0.014–0.020	0.051×0.016
p	0.030–0.050	0.011–0.022	0.041×0.015
q	0.035–0.065	0.013–0.020	0.047×0.0146
r	0.024–0.045	0.011–0.020	0.039×0.0163
s	0.040–0.054	0.014–0.020	0.044×0.015
t	0.033–0.040	0.014–0.018	0.034×0.143
1289 row a	0.062–0.073	0.013–0.026	0.071×0.018
b	0.071–0.091	0.010–0.023	0.082×0.016
c	0.064–0.084	0.013–0.022	0.074×0.016
d	0.051–0.064	0.015–0.024	0.056×0.020
1282 row a	0.031–0.042	0.017–0.026	0.038×0.021
b	0.024–0.035	0.010–0.021	0.028×0.016
c	0.021–0.038	0.010–0.021	0.032×0.018
d	0.045–0.082	0.024–0.032	0.058×0.027
e	0.047–0.061	0.027–0.036	0.050×0.030
f	0.047–0.064	0.024–0.033	0.054×0.026
g	0.018–0.038	0.019–0.029	0.033×0.023
h	0.034–0.048	0.012–0.025	0.042×0.021
1355 row a	0.040–0.045	0.013–0.023	0.042×0.017
b	0.036–0.048	0.014–0.023	0.042×0.018
c	0.036–0.051	0.018–0.027	0.042×0.023
d	0.046–0.054	0.016–0.025	0.052×0.020
e	0.063–0.067	0.014–0.018	0.064×0.016
1360 row a	0.031–0.039	0.011–0.018	0.035×0.015
b	0.028–0.033	0.011–0.020	0.031×0.015
c	0.032–0.037	0.010–0.022	0.030×0.014
d	0.028–0.037	0.011–0.022	0.033×0.015
e	0.036–0.039	0.011–0.022	0.036×0.015
f	0.032–0.041	0.011–0.027	0.039×0.019

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MISSISSIPPIAN CRINOID FAUNA FROM THE BANFF FORMATION, SUNWAPTA PASS, ALBERTA

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ABSTRACT—A Mississippian crinoid fauna of Kinderhookian age from the Banff formation of Alberta is described. Thirty genera and fifty-two species are recognized. Four new genera, *Ramulocrinus*, *Maligneocrinus*, *Athabascacrinus*, and *Sunwaptacrinus*, are described. Twenty-one new species, *Pelecocrinus banffensis*, *P. primordialis*, *Cradeocrinus warreni*, *Goniocrinus angulatus*, *Dinotocrinus albertaensis*, *Linocrinus faculensis*, *Decadocrinus saskatchewanensis*, *Ramulocrinus nigelensis*, *Forbesiocrinus withersi*, *Eutaxocrinus pulvinatus*, *Paraichthyocrinus seversoni*, *Rhodocrinites brewsteri*, *R. cirrusi*, *Cribanocrinus wilsoni*, *Maligneocrinus medicinensis*, *Athabascacrinus colemanensis*, *Aorocrinus banffensis*, *Sunwaptacrinus brazeauensis*, *Cactocrinus kuenzii*, *Platycrinites sunwaptaensis*, and *P. decadactylus*, are described. Twenty-four species are represented by fragmentary materials and are not identified specifically.

INTRODUCTION

RECONNAISSANCE work in the Sunwapta Pass area, Jasper Park, Alberta, late in the summer of 1948 demonstrated unusually fossiliferous rocks in the Mississippian Banff formation. A research party, sponsored by the Wisconsin Alumni Research Foundation, was sent into the field in the summer of 1949 for the purpose of studying the whole area in detail.

The fossils found in the Banff formation, particularly in the area immediately adjacent to Sunwapta Pass, were so excellently preserved that we believe special mention should be made of the fact. Some of the finest museum specimens in North America can be collected from the slopes of Nigel Peak and the first subsidiary peak to the south.

Rocks assigned to the Banff formation in the Sunwapta Pass area are slightly over 2000 feet in thickness, the thickest section of Banff rocks we have encountered in Canada. They are unusual in that fossils may be obtained throughout the section. In general, the numbers of specimens and the excellence of preservation increases upward in the section.

Fossil crinoids were found widely distributed both vertically and laterally throughout the area within the Banff formation. The greater part of the fauna described in this paper came from a single zone on the north flank of the first peak south of Nigel Peak. Some specimens were collected, however, from the slopes of Nigel Peak, Mt. Cirrus, Mt. Coleman and later in the summer from the area between Medicine and Maligne lakes.

The Banff formation in the Sunwapta Pass area consists of a remarkably cyclic sequence in which each major cycle consists of a soft, gray, shaly limestone followed by a harder, gray to black, crinoidal, scarp-forming limestone. The main crinoid zone on the north flank of the peak south of Nigel Peak lies within one of the shaly units approximately 1400 feet above the base.

The Banff formation is overlain by massive, scarp-forming limestones of the Dessa Dawn formation. The contact between the Banff and and Dessa Dawn is transiticnal and there are no indications of faunal break. The extra thickness assigned to the Banff formation in the Sunwapta Pass area is due to the fact that typical Dessa Dawn lithology is not developed as soon in this area. Beds assigned to the upper part of the Banff in the Sunwapta Pass area can be traced northward into beds assigned to the lower part of the Dessa Dawn formation in the Wapiti Lake area (Spreng, 1950, p. 102).

Assignment of age within the Mississippian system to the thick Banff-Dessa Dawn sequence is difficult and will not be settled

until much more work has been completed dealing with the western Mississippian sections in North America. Great care must be exercised in the use of fossils in making correlations back to Mississippi Valley formations since ranges of genera and species have not been established in this area. Common guide fossils with well-established ranges in the Mississippi Valley area are found in entirely different parts of the section in the western area. For example, species of *Pentremites* closely comparable with Meramec and Chester species in the Mississippi Valley area occur abundantly in the Banff formation in association with common Kinderhook brachiopods. Large spiriferoid brachiopods commonly restricted to Osage beds in the Mississippi Valley area are found in the Banff formation in association with faunas with overwhelming Kinderhookian affinities.

Faunal lists from these western sections are rarely reliable because they have been compared to species described only from the Mississippi Valley area. In the majority of cases they are new species closely related to the Mississippi Valley forms and in lists they can be made to represent almost anything that is in the mind of the author. Fossils can be used to support the total picture of field evidence but they should never be used exclusive of field evidence in age determination other than in a very general way.

The crinoid fauna described in this paper will be shown to be almost exclusively Kinderhookian in aspect with many genera and species filling in gaps in evolution between Devonian and later Mississippian forms. Associated with the crinoid fauna is an abundant brachiopod, bryozoan, coral fauna, the more common elements of which are listed here. Numerous zaphrentid and cyathophylloid corals on which no studies have been made, and large numbers of fenestrate bryozoans also not studied, occur abundantly. Among the brachiopods the following elements are recognized: *Leptaena analoga* (Phillips), *Schellwienella* cf. *S. alternata* Weller, *Chonetes multicostata* Winchell, *Dictyoclostus* n. sp., between *D. arcuatus* and *D. fernglenensis*, *Rhipidomella missouriensis* (Swallow), *Dielasma* sp., *Delthyris solidirostris* (White), *D. missouriensis* (Weller), *Spirifer biplicoides* Weller, *S. platynotus* Weller, *Spirifer* n. sp., between *S. gregeri* and *S. rowleyi*, *Spirifer* n. sp. related to *S. rowleyi* but more finely lined, *Spirifer* n. sp. ancestral to *S. forbesi* Norwood and Pratten, *Brachythyris chouteauensis* Weller, *Martinia* sp., *Syringothyris* n. sp. between *S. hannibalensis* and *S. subcuspidatus*, *Cliothyridina obmaxima* (McChesney), *Cliothyridina incrassata* (Hall), *Cliothyridina* n. sp., *Hustedia* sp., *Athyris* n. sp., between *A. hannibalensis* and *A. lamellosa*, *Composita* n. sp., ancestral to *C. subquadrata*.

The blastoids are represented by *Cryptoblastus* sp., *Metablastus* sp., *Pentremites* n. sp., related to *P. elongatus*, *Pentremites* cf. *P. conoideus* Hall.

Among the above listed species only *Cliothyridina obmaxima* is limited to Osage beds in the Mississippi Valley area. The large spiriferoid brachiopods closely related to *S. rowleyi* would be commonly considered as Osage species if found in the Mississippi Valley area. Many of the new species occupy positions in the scale of evolution between forms heretofore considered as Kinderhookian and Osagian species.

On the basis of the preponderance of Kinderhook species, particularly the typical rhodocrinitid-cactocrinid fauna, we are assigning the Banff formation entirely to the Kinderhook. We are of the opinion that the thinner Mississippi Valley Kinderhook formations represent a series of transgressions of a single sea from which the Banff sediments were deposited.

A brachiopod fauna consisting of large brachiopods was collected from the basal beds of the Dessa Dawn formation in the pass approximately 200 yards south of the peak south of Nigel Peak in which a preponderance of Osage forms are present. The following fauna was collected: *Chonetes illinoisensis* Worthen, *Dictyoclostus* cf. *D. inflatus* (McChesney), *Dictyoclostus* cf. *D. viminalis* (White), *Echinoconchus* cf. *E. alternatus* (Norwood and Pratten), *Spirifer platynotus* Weller, *Spirifer rowleyi* Weller, *Spirifer* cf. *S. grimesi* Hall, *Brachythyris suborbicularis* (Hall), and *Syringothyris typus* Winchell. The Dessa Dawn formation was assigned a late Kinderhook age (Laudon et al. 1949, p. 1540) in our first interpretation in the Wapiti Lake area. The presence

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of this brachiopod fauna throws some doubt on the original age assignment. As yet none of the typical early Osage crinoid faunas have been found in the Dessa Dawn.

Illustration of fossil crinoids poses special problems not encountered in most invertebrates. Classification is based on plate structure, and sutures between plates are commonly discernible only with the aid of a binocular and correctly directed light. Excellent photography often produces nothing more enlightening than variously colored and shaped mud lumps. Unretouched illustrations of such specimens only add to the confusion already existing in the literature. The Sunwapta crinoids are black in color thus further complicating photography.

Accordingly both unretouched photographs and restorations are presented with this paper. Restorations were prepared by sketching the structure on a photographic enlargement with the aid of a binocular. The photograph was then bleached and finally shaded with carbon pencil again with the aid of a binocular.

TYPES

The abbreviation GSC used in indicating repository of types and figured specimens refers to Geological Survey of Canada.

ACKNOWLEDGMENTS

Special recognition is acknowledged for Mrs. Dorothy Severson for her meticulously correct technical art work in connection with preparation of all restorations.

The writers are indebted to Dr. G. S. Hume, Dr. A. Bell, Dr. George Beales, and Dr. Peter Harker, Geological Survey of Canada, for aid with the project.

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SYSTEMATIC PALEONTOLOGY

BARYCRINIDAE Jaekel, 1918
Genus PELLECRINUS Kirk, 1929
PELLECRINUS sp.
Plate 65, figs. 1–2

This species is represented by a single incomplete, badly fractured specimen. It has been tentatively referred to *Pellecrinus* but the diagnostic characters that might validate this assignment cannot be determined on the specimen. The posterior side is damaged and it is not possible to determine either the presence of X or RA in the cup or whether the RA, if present, is quadrangular or pentagonal.

We hesitate to propose specific names for species that are represented by such incomplete materials, hence this specimen is figured only for its stratigraphic value.

IBB apparently five, forming a definite part of the lateral cup wall. BB very large, forming at least two-thirds of the lateral cup wall, characterized by an unusually strong, rounded ray ridge that bifurcates and continues on to the center of the R. A much smaller rounded ridge projects laterally to the adjoining R. Plate corners unusually deeply depressed. RR wider than high, curving abruptly inwards at the top, facet directed obliquely upward, occupying more than half of the width of R. RR with four conspicuous, rounded ridges, two radiating obliquely downward to center of B, two laterally directed to adjacent RR. Anal structures not determinable. Plate sutures sinuous. Column apparently large.

Remarks.—This species represents a highly specialized end product apparently derived from the Barycrinidae. It differs markedly from *P. hexadactylus* (Lyon and Casseday, 1860, p. 74) the genotype, because of its strong ray ridges. More complete materials may eventually demonstrate that this species is more closely related to the Ampheristocrinidae and that it has evolved from *Vasocrinus*. If the arms are pinnulate and the RA pentagonal, the species cannot be referred to the Barycrinidae.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9901.

CYATHOCRINITIDAE Bassler, 1938
Genus CYATHOCRINITES Miller, 1821
CYATHOCRINITES sp.
Plate 65, figs. 3–7

The genus *Cyathocrinites* as now recognized among inadunate crinoids is in need of extensive revision. Species assigned to the genus now range in age from Silurian to Permian. Primitive Silurian species assigned to the genus have conical cups with the IBB forming a prominent part of the lateral cup wall. One stock among the species now assigned to the genus developed a globular rounded cup with the IBB not showing on the lateral wall. The anal sac, always short, varies in length to half the length of the arms. The uniserial, isotomously branching non-pinnulate arms remain little changed throughout the history of the genus.

Since a very large number of more or less incompletely described Mississippian species closely resemble the species we have figured here from the Banff formation, we have decided not to further complicate the literature until a complete study of the genus *Cyathocrinites* can be undertaken. Hence no specific name is proposed for the Banff species and it is figured for stratigraphic value. A brief description is presented.

Cup low, globular, IBB not visible on lateral wall. Cup averages 5 mm. in height with the arms reaching a length of at least 30 mm. IBB small, directed slightly downward, confined to basal concavity. BB large, curved upward, vertically directed at top. A low node marks the center in some specimens. RR five, width 5 mm., height 3 mm., facets deeply arcuate, directed obliquely upward. X large, resting on truncated upper surface of PB, in contact laterally with RPR and LPR. PB high, base of X at mid-height of RR. Tube short, stout. Arms isotomous, uniserial, branches widely flaring, axillary brachials completely separating higher brachials. PBrr varying from two to four.

Column round, proximal portion of alternately expanded columnals.

Remarks.—This species of *Cyathocrinites* represents an advanced stage of development of the genus in which the cup is round and the IBB are in a concavity.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9902, 9903, 9904, 9905.

CYATHOCRINITES sp.
Plate 65, fig. 8

A second species of *Cyathocrinites* is present in the Banff fauna. It is represented by two fragmentary specimens in our collections. It is characterized by stellate plate markings and IBB that are visible on the lateral cup wall. The specimens are too fragmentary to warrant assignment of a specific name. It is figured for stratigraphic value.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9906.

Unfigured specimen.—GSC No. 9907.

POTERIOCRINITIDAE Bassler, 1938
Genus POTERIOCRINITES Miller, 1821
POTERIOCRINITES sp.
Plate 65, figs. 9–10

A single fragmentary specimen of *Poteriocrinites* occurs in the Banff formation and marks one of the rare occurrences of that genus in North America. It is figured for stratigraphic value and a specific name is withheld until more complete materials are available.

The cup is steeply conical, IBB low, making a definite part of the lateral cup wall, BB higher than wide, RR height equals width, with typical markedly curved facet that occupies approximately one-half of the upper surface of the RR. Facets directed obliquely upward and projecting slightly laterally. RA, X, and Rt in normal position. Low stellate ridges mark plates and the corners are depressed.

Remarks.—This specimen closely resembles *P. crassus* Miller from the Tournaisian of Scotland.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9908.

PELECOCRINIDAE Kirk, 1941
Genus PELECOCRINUS Kirk, 1941
PELECOCRINUS BANFFENSIS n. sp.
Plate 65, figs. 13–15; plate 69, fig. 1

This spectacular species of *Pelecocrinus* is

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represented by three partially complete specimens in our collections. It is the largest and most specialized species of *Pelecocrinus* in the Banff formation.

Crown open, incomplete in all specimens, but apparently not flaring beyond mid-length. Length of holotype (incomplete) 68 mm., and estimated to exceed 90 mm. in length when complete.

Cup low, bowl-shaped, width approximately twice height. IBB small, projecting beyond column, laterally directed, tips curved upward slightly making them visible on the lateral wall of the cup. BB wider than high, height, 7 mm., width 9 mm., corners deeply impressed. RR width 10 mm., height 6 mm. on paratype, markedly arcuate laterally, corners deeply impressed, a low rounded ridge radiates from the center of each radial facet to the radial-basal sutures. The ridge is accentuated near the radial-basal suture and dies out near the radial facet. The radial facet is markedly arcuate, occupies only slightly more than half of the upper surface of R, and is marked by a slight brim at its contact with the outer surface of the R. RA almost as large as PB, resting in the normal position on truncated surfaces of PB and RPB, in contact laterally with X and RPR, and overlain by Rt. X slightly smaller than RA.

Arms having characteristic open pattern due to axillary facets being directed obliquely upward. Axillary plates large, completely separating higher brachials. Arms rounded, characteristic sinuous pattern common to early Kinderhook species only poorly developed. PBrr one, except in A ray where there are eight, stout, slightly constricted at mid-length. SBrr seven to eight. TBrr nine in one branch, all others incomplete; 14 in one branch without axillary termination. Brr cuneiform, each slightly constricted at mid-length, each terminated with a slight node remnant of the mid-ridge immediately below the succeeding Br contact. Pinnule facet essentially in middle of Br instead of on the oblique upper surface. Pinnules slender, directed abruptly upward, almost parallel to arm.

Sac long, strong, apparently rising well toward full length of arms. Plates much wider than high, irregularly hexagonal, marked by a single, strong horizontal ridge in the upper part and by six divergent ridges in the lower part.

Column weakly pentagonal in proximal part; distal part unknown.

Remarks.—The very distinctive sac separates this species of *Pelecocrinus* from all others. The size of the adult form and the shape of the cup are closely comparable with *P. insignis* Kirk, the genotype. The arms of *P. banffensis* are markedly less cuneiform than those of *P. insignis*.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—GSC, holotype No. 9911; paratypes Nos. 9912, 9913.

Pelecocrinus primordialis n. sp.
Plate 65, fig. 17; plate 69, fig. 2

This species of *Pelecocrinus* is represented by a single partially complete crown in our collections. Although incomplete, the specimen makes available considerable evidence with regard to the somewhat controversial problem of the evolution of the Pelecocrinidae. The genus *Pelecocrinus* (Kirk, 1941, p. 82) was erected with *P. insignis* Kirk, an advanced specialized form from the Keokuk beds, as the genotype. *P. insignis* is characterized by a widely flaring, campanulate cup with deeply indented plate corners and weak stellate markings. The R facets are arcuate and occupy approximately half of the upper surface of the R. The arms are open, branch only two or

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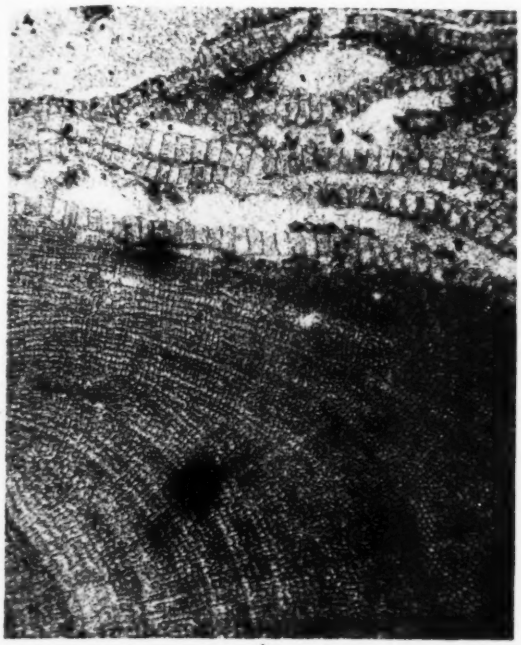
Explanation of Plate 64

Fig. *1*—*Lithophyllum sierra-blancae* Howe and *Lithoporella melobesioides* Foslie. Homoeotype (slide 1282) ×75. A portion of a branch of *Lithophyllum* showing the tissue with several thalles of the *Lithoporella* above. (p. 540)

2—*Lithophyllum* sp. *B.* (slide 1283a) ×100. An oblique section showing tissue and a conceptacle. (p. 541)

3—*Mesophyllum atascaderum* Johnson and Tafur. Holotype (slide 1362) ×100. A detail of the tissue showing growth zones and a conceptacle. (p. 539)

4—*Lithothamnion limaensum* Johnson and Tafur, n. sp. Holotype (slide 1285) ×100. A portion of a crust showing hypothallus (at left), perithallus, and conceptacle scar. (p. 538)



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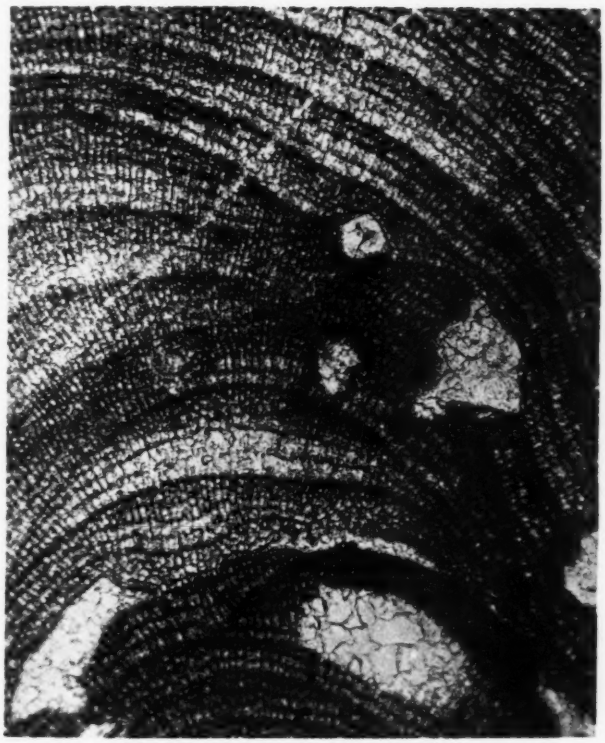

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4

Johnson and Tafur, Eocene Algae from Peru

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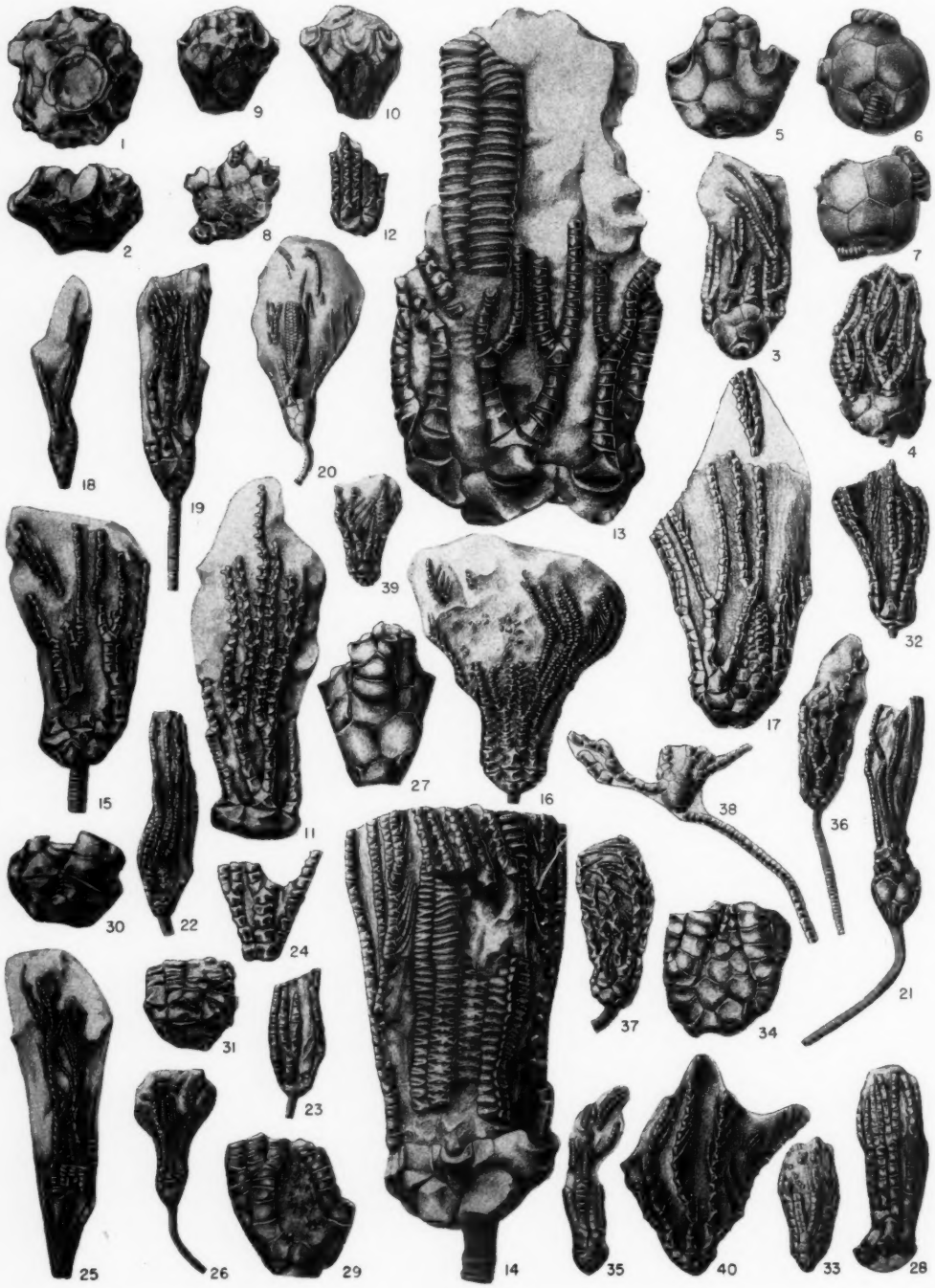

Laudon, Parks and Spreng, Mississippian Crinoids from Canada

three times and the brachials have a strange, distinct, pinnule facet developed only on *Pelecocrinus*. Kirk (1941, p. 83) correctly observed that *Pelecocrinus* was most closely related to *Abrotocrinus*. *Stinocrinus*, *Hylodecrinus*, and *Cosmetocrinus*, new genera erected by Kirk (1941, p. 84, p. 85, p. 86, respectively) were placed in a new family, Pelecocrinidae. Of these genera we now think that only *Cosmetocrinus* was evolved from the same genetic line. Such forms as *Stinocrinus* and *Hylodecrinus* with two PBrr we believe to have been evolved through the more primitive Blothrocrinidae. Moore and Laudon (1943, pp. 23 and 43) have indicated that the Pelecocrinidae evolved from the Poteriocrinitidae, an observation based mainly on the restricted radial facet of both families. We believe that this is a normal case of parallel evolution that has been repeated many times in the history of the Crinoidea. The curved radial facet allows for motion of the arm in more than one plane as compared to the single direction of motion allowed by the straight hinge type of facet of the early forms.

Pelecocrinus primordialis is the most primitive species of *Pelecocrinus* known to us. It has a comparatively deep, somewhat conical, smooth-plated cup suggestive of ancestry more primitive than most species of *Abrotocrinus*. The relatively open arms that branch only two or three times are considered by us to be more primitive than the multiple branching arms of *Abrotocrinus*. We consider that *Abrotocrinus* is a somewhat advanced form that branched from a more primitive ancestor of *Pelecocrinus*.

P. primordialis with its open arm structure, typical *Pelecocrinus*-type of pinnule facets, progressive deepening and broadening of the cup, and slightly restricted R

EXPLANATION OF PLATE 65

All illustrations are drawings, and are natural size unless otherwise indicated.

FIGS. *1, 2*—*Pellecrinus* sp. *1*, basal view, ×2/3; *2*, lateral view, ×2/3, GSC No. 9901. (p. 546)

3–7—*Cyathocrinites* sp. *3*, posterior view, GSC No. 9902; *4*, anterior view, GSC No. 9903; *5*, posterior view, ×2, GSC No. 9904; *6*, basal view, ×2; *7*, anterior view, ×2, GSC No. 9905. (p. 547)

8—*Cyathocrinites* sp. Basal view, GSC No. 9906. (p. 547)

9, 10—*Poteriocrinites* sp. *9*, posterior view; *10*, anterior view, GSC No. 9908. (p. 547)

11, 12—*Pelecocrinus* sp. *11*, right anterior view, GSC No. 9909; *12*, anterior view, GSC No. 9910. (p. 550)

13–15—*Pelecocrinus banffensis* Laudon, Parks and Spreng, n. sp. *13*, holotype, left anterior view, GSC No. 9911; *14*, paratype, lateral view, GSC No. 9912; *15*, paratype, right anterior view GSC No. 9913. (p. 547)

16—*Linocrinus faculensis* Laudon, Parks and Spreng, n. sp. Holotype, anterior view, GSC No. 9933. (p. 555)

17—*Pelecocrinus primordialis* Laudon, Parks and Spreng, n. sp. Holotype, posterior view, GSC No. 9914. (p. 548)

18–21—*Cradeocrinus warreni* Laudon, Parks and Spreng, n. gen., n. sp. *18*, holotype, posterior view, GSC No. 9915; *19*, paratype, anterior view, ×2, GSC No. 9916; *20*, paratype, posterior view GSC No. 9917; *21*, paratype, lateral view, GSC No. 9918. (p. 551)

22, 24—*Goniocrinus angulatus* Laudon, Parks and Spreng, n. sp. *22*, holotype, anterior view, GSC No. 9919; *24*, paratype, anterior view, ×2, GSC No. 9920. (p. 552)

23, 33—*Blothrocrinus* sp. *23*, posterior view, GSC No. 9923; *33*, anterior view, GSC No. 9924. (p. 553)

25—*Cradeocrinus* sp. Lateral view, GSC No. 9921. (p. 551)

26—*Blothrocrinus* sp. Left posterior view, GSC No. 9925. (p. 553)

27—*Blothrocrinus* sp. Left posterior view, ×2, GSC No. 9922. (p. 553)

28—*Cosmetocrinus* sp. Anterior view, ×2, GSC No. 9926. (p. 553)

29–31—*Abrotocrinus* sp. *29*, posterior view, GSC No. 9927; *30*, left posterior view, GSC No. 9928; *31*, right anterior view, GSC No. 9929. (p. 554)

32—*Dinotocrinus albertaensis* Laudon, Parks and Spreng, n. gen., n. sp. Holotype, right anterior view, GSC No. 9930. (p. 554)

34—*Pachylocrinus* sp. Posterior view, ×2, GSC No. 9931. (p. 555)

35—*Hylodecrinus* sp. Anterior view, ×2/3, GSC No. 9932. (p. 555)

36–38—*Decadocrinus brazeauensis* Laudon, Parks and Spreng, n. sp. *36*, holotype, anterior view, GSC No. 9934; *37*, paratype, anterior view, GSC No. 9935; *38*, paratype, posterior view, GSC No. 9936. (p. 556)

39–40—*Ramulocrinus nigelensis* Laudon, Parks and Spreng, n. gen., n. sp. *39*, paratype, anterior view, GSC No. 9938; *40*, holotype, anterior view, GSC No. 9937. (p. 558)

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facets, forecasts the development found in such specialized forms as *P. insignis*, the genotype.

Crown open, not expanded upward, reaching a length of 53 mm. (incomplete) in the holotype. Cup flattened at base, moderately conical, not broadly expanded, deeply bowl-shaped. Width at arm bases 9 mm., height 7 mm. IBB small, barely visible on lateral wall. BB height equals width. PB high, reaching to mid-height of LPR. RR wider than high, width 4 mm., height 2.4 mm., facet only slightly less than full width of R, only slightly arcuate. RA slightly smaller than X, in normal position resting on the laterally truncated surface of PB and RPB, laterally in contact with X and RPR, in contact above with Rt. X in normal position on truncated upper surface of PB rising considerably higher than LPR. Lower sac plates normal, hexagonal; upper part of sac unknown.

PBrr one, markedly constricted at mid-length, height 4.9 mm., facets directed obliquely upward, entirely separating SBrr. Anterior PBr not known. SBr long, formed by two Brr united by syzygy. $SBrr_1$ varying, between six and nine, slightly cuneiform with feebly developed, acuminate mid-ridge. Pinnule facets laterally directed from anterior end of Br, facets rounded, laterally abruptly projected, typical of later species of *Pelecocrinus*. Axillary SBrr large, conspicuous, facets directed obliquely upward, completely separating TBrr. TBrr variable, 16 present in one branch, 18 present in another branch without terminal axillary TBr.

Pinnules relatively slender, directed abruptly upward.

Proximal columnals pentagonal, others unknown.

Remarks.—We have followed the practice in this paper of not assigning specific names to species represented by single specimens as incomplete as *P. primordialis*. Because this species contains a large number of primitive characters that forecast the later species of *Pelecocrinus* we have decided to assign a specific name. Future work in the prolific fossil beds of the Banff formation will undoubtedly uncover more materials so that a more complete description can be offered.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—GSC holotype No. 9914.

PELECOCRINUS sp.
Plate 65, figs. 11–12

This species is presented for its stratigraphic value. It is represented by two somewhat damaged specimens in the Banff fauna. The larger specimen appears to be related to *P. parviglyptus* Laudon and Beane (Laudon and Beane, 1937, p. 257) from the Hampton beds at LeGrand, Iowa.

Crown open, arms branching infrequently, incomplete, height at least 55 mm. Cup conical, low, rapidly expanding; IBB not visible on lateral cup wall. BB laterally directed and curved upward to make up the lower part of the cup wall. RR much wider than high. Arms branching on PBr_1 except in the anterior ray where there are nine PBrr. Sbrr between eight and ten. TBrr between 12 and 16. All Brr cuneiform, angular, marked by an acuminate mid-ridge directed in zig-zag fashion on alternate plates. The mid-ridge ends in a low node at the top of each Br. A very strong pinnule-bearing projection, laterally directed, rises from the top of each Br. Axillary arm plates are large, dividing higher Brr, facets directed obliquely upward. The mid-ridge branches on axillary plates.

X structures are not available for study on the Banff specimens.

Remarks.—The unusual angular appearance of the arms of this species coupled with the laterally directed projections that bear the pinnule facets make it easily separable from other species assigned to this genus.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9909–9910.

OTTAWACRINIDAE Moore and Laudon, 1943

The Ottawacrinidae were derived from the more primitive Dendrocrinidae and differ from them mainly in the manner of branching of the arms. The heterotomous ramule-like arm branches of the Ottawacrinidae separate them from the Dendrocrinidae. *Ottawacrinus* retains the more primitive RA directly below RPR but all

younger genera in the family have a quadrangular RA that has shifted from directly beneath RPR toward the posterior. The RA is quadrangular in the Botryocrinidae, another offshoot from the dendrocrinids. True pinnules are developed in some genera within the present ascribed limits of the Botryocrinidae. In the Poteriocrinitidae and Glossocrinidae, both offshoots from the Botryocrinidae, the RA has been further shifted toward the posterior and upward bringing it in contact with PB and RPB beneath, laterally in contact with X and RPR and beneath Rt. This is the normal position of RA in a large number of the later Paleozoic Inadunata. Both Poteriocrinitidae and Glossocrinidae are pinnulate.

Difficulties in classification are encountered when species are found with some elements in the primitive stage of development and others in advanced stages. Such conditions are met in both *Cradeocrinus* (Goldring, 1923, p. 347) and *Iteacrinus* (Goldring, 1923, p. 344). In both genera the arms retain the primitive non-pinnulate dendrocrinoid structure but the RA is pentagonal and in the advanced position in contact with Rt. Both *Cradeocrinus* and *Iteacrinus* are assumed by the writers to have evolved from the dendrocrinids through some form closely related to *Lasiocrinus* (Kirk, 1914, p. 481). *Lasiocrinus* differs from the other two genera in that the RA retains its primitive quadrangular shape.

Genus CRADEOCRINUS Goldring, 1923

CRADEOCRINUS WARRENI n. sp.

Plate 65, figs. 18–21; plate 69, fig. 3

A single species in the Banff fauna is referred provisionally to *Cradeocrinus*. The species is based on four specimens, all somewhat incomplete.

Cup acutely conical, height of holotype 4.9 mm., width at arm bases 4.1 mm. IBB large, erect, making a conspicuous part of the lateral wall, height 1.6 mm., width 1.2 mm. BB large, height 2.4 mm., width 2.2 mm. RR slightly wider than high, width 2.3 mm., height 1.2 mm. RA small, pentagonal, resting on PB and RPB, laterally in contact with X and RPR, in contact beneath with Rt. X slightly larger than RA, much smaller than R, resting on truncated surface of PB. Plates smooth, corners not depressed.

Sac long, slender, rising approximately two-thirds of the height of the arms, consisting of vertical rows of hexagonal plates, not stellate, and apparently without a median sac ridge.

Arms long slender, delicate, slightly sinuous in appearance. PBrr three, first occupying almost full width of R, second slightly constricted, third axillary, expanded slightly. SBrr three, long, narrow, not cuneiform, third axillary giving rise to long unbranched ramule that reaches to full height of arms. TBrr three or four giving rise to ramule on opposite side of the arm. Arms branch at least once more, all damaged and incomplete.

Column round, of alternately expanded columnals.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area.

Types.—Holotype GSC No. 9915; paratypes GSC Nos. 9916, 9917, 9918.

CRADEOCRINUS sp.

Plate 65, fig. 25

This species is represented by a single specimen in a very bad state of preservation. The IBB are missing, only the basal plates of the sac are preserved, and only the ambulacral side of two arms are available for study. The entire specimen has been perforated by scavengers so that even brachial sutures in the arms are largely obscured. We recognize that this fossil departs quite radically from *Cradeocrinus* and that ultimately, when more complete materials are available, a new genus will probably have to be established to care for it. We are placing it tentatively with *Cradeocrinus* since that seems to be its nearest relative. It is figured here for its stratigraphic value.

Crown unusually long and slender with very delicate arms. Cup steeply conical, height estimated at 14 mm., width at arm bases 6 mm. IBB missing, but apparently relatively short as shown by the impression of the column on the rock. BB unusually long and expanding upward, width 1.4 mm. at base, 3 mm. wide at top, height 6 mm. RR much higher than wide, height 4.5 mm., width 2.7 mm., facet slightly arcuate, occupying considerably more than half of

upper surface of R. PBrr three, rounded, slender, completely non-cuneiform. Arms very long, very delicate and slender, giving off relatively strong ramules on alternate sides of every other brachial. It is not possible to be certain that the pinnules arise from every other Br in the lower part of the arms due to poor preservation.

A few plates are preserved in the lower part of the sac. They consist of hexagonal plates, wider than high, and apparently stellate.

The impression of the column appears to be round and of alternately expanded columnals.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9921.

Genus GONIOCRINUS Miller and Gurley, 1890

GONIOCRINUS ANGULATUS n. sp.

Plate 65, figs. 22 and 24; plate 69, fig. 4

The genus *Goniocrinus* poses some of the same problems that arise in connection with *Cradeocrinus*. *Goniocrinus* has the strong median ridge running the full length of the sac which characterizes all genera in the Glossocrinidae. However *Goniocrinus* retains primitive characters apparently inherited from the Ottawacrinidae such as non-pinnulate arms and the quadrangular RA. *Goniocrinus* was placed in the Glossocrinidae on the basis of the median anal ridge by Laudon (1933, p. 61; 1937, p. 254). Moore and Laudon (1943, p. 55) place *Goniocrinus* in the more primitive Ottawacrinidae because of the more significant primitive arm structure and the quadrangular RA. We are retaining *Goniocrinus* in the Ottawacrinidae in this paper with full understanding that eventually a new family will have to be proposed to house these intermediate forms. The unusually small BB found in *G. angulatus* also characterize some genera in the Glossocrinidae.

The genus *Goniocrinus* stands apart from other related genera because of the very distinctive strange Brr in the lower portion of the arms.

Two specimens of *Goniocrinus*, one fragmentary and of little value, are present in our collections.

Crown constricted immediately above cup, arms closely packed, length more than 30 mm. Cup steeply conical, IBB conspicuously large, forming an important part of the lateral cup wall. BB unusually small, smaller than IBB, RR wider than high, conspicuously larger than BB, facets slightly arcuate, occupying slightly more than half of the upper surface of R. PBrr three or four, narrow at base, flaring abruptly to form rounded, laterally projecting lobes above the mid-length, sutures deeply impressed, upper surface of each PBr flaring outward making succeeding PBr appear to arise from slightly beneath the underlying PBr. Main arm rays strong, lower Brr having the characteristic rounded flaring lobe which becomes weaker upward and disappears at about the mid-length of the arms. Upper arm brachials with an acuminate ridge making them roughly triangular in outline. Strong ramules given off on alternate sides, from every third or fourth Br in lower arms and regularly from every second Br in upper arms. Axillary Br facets directed at a slightly oblique angle to main direction of arms giving the arms a remarkably sinuous appearance.

Anal and sac not available for observation.

Column pentagonal, at least in proximal columnals. A few short segments of cirri made up of very thin cirrals are preserved with one specimen indicating that whorls of cirri are probably given off at intervals along the column as in other species of *Goniocrinus*.

Remarks.—*Goniocrinus angulatus* n. sp. differs from *G. sculptilis* Miller and Gurley and *G. maximus* Laudon, its closest relatives, in that *G. angulatus* is characterized by remarkably small BB. Neither *G. sculptilis* Miller and Gurley and *G. maximus* Laudon have ramules given off more often than every third Brr in the upper arms. The angular, distinctly sinuous arm pattern of *G. angulatus* also readily distinguishes it from other known species.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9919; paratype GSC No. 9920.

BLOTHROCRINIDAE Moore and Laudon, 1943

Genus BLOTHROCRINUS Kirk, 1940

Due to the piece-work methods used in the

development of the classification of inadunate crinoids without reference to the genetic relationships of the group as a whole, large gaps now exist in the framework of classification. In the case of inadunate crinoids with a high turbinate cup, three anals in the cup and two PBrr, both *Blothrocrinus* and *Cydrocrinus* represent specialized genera with relatively complex arm structures. No suitable generic names exist today for the more primitive transitional ancestors of these genera. Four specimens representing three species are tentatively referred to *Blothrocrinus* in this paper.

BLOTHROCRINUS sp.
Plate 65, fig. 27

This single fragmentary specimen consisting of a cup with a few of the lower arm brachials attached appears to represent the genus *Blothrocrinus* in its present ascribed limits. The cup is closely comparable to that of *B. spartarius* (Miller and Gurley) from the Hampton beds at LeGrand, Iowa. It is figured for its stratigraphic value.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9922.

BLOTHROCRINUS sp.
Plate 65, figs. 23 and 33

Two specimens, probably representing immature individuals, are figured for their stratigraphic value. Both are simple, generalized individuals that might be referred to several genera. The cup is conical, with the IBB showing on the lateral wall and two PBrr are present. In both specimens the cup expands more rapidly than is common for *Blothrocrinus*. They are assigned to *Blothrocrinus* with the full understanding that they may represent immature individuals of any one of several genera.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9923, 9924.

BLOTHROCRINUS sp.
Plate 65, fig. 26

This specimen represents a new genus, referable at present only to *Blothrocrinus* but departing widely from *Blothrocrinus* both in structure and genetic origin. The cup shape, anal plates and lower arm brachials are comparable to *Blothrocrinus* and both genera probably came from a common ancestor. The arms, branching relatively few times and with cuneiform, specialized brachials closely resembling the type found in *Pelecocrinus*, depart radically from the present ascribed limits of *Blothrocrinus*. We have refrained from proposing a new generic name because of the single incomplete specimen available for study and because proposal of one new name would represent only a small portion of the job of revision within this group.

Cup steeply conical, IBB large, making an important part of the lateral wall of the cup. BB large, higher than wide. RR slightly wider than high, facet essentially straight, occupying the full width of R. RA and X in normal position.

PBrr two, markedly constricted at mid-length. SBrr 10 to 12, slightly cuneiform, with markedly projecting pinnule facets directed only slightly upward at the top of each Br. Pinnules strong. Sac of vertical rows of stellate, hexagonal plates apparently not reaching to full height of arms.

Column round.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9925.

Genus COSMETOCRINUS Kirk, 1941
COSMETOCRINUS sp.
Plate 65, fig. 28

Cosmetocrinus is represented in the Banff fauna by a single specimen in which both BB and IBB are missing. It is figured for stratigraphic value.

The unusually long PBr and simple long arm Brr are not found in other species of *Cosmetocrinus*. The arms of the Banff species branch only once beyond the PBr and in this character resemble most closely *C. legrandensis* (Miller and Gurley) from the Hampton beds (Kinderhookian) at LeGrand, Iowa. The crown of the Iowa species flares abruptly at the mid-length while that of the Banff species shows no tendency to flare. The simple, round arm Brr with straight, entirely non-cuneiform Br indicate very primitive origins such as is common to Devonian inadunates in related stocks. It is possible that the Banff species represents

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the type of ancestral stock from which the later, slightly more specialized species of *Cosmetocrinus* evolved.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9926.

PACHYLOCRINIDAE Kirk, 1942
Genus ABROTOCRINUS Miller and Gurley, 1890

Both *Abrotocrinus* and *Pachylocrinus* are characterized by low bowl-shaped cups in which the IBB are laterally directed and often extend only slightly beyond the column. Both genera have endotomous arms that branch several times and both have R facets that occupy the full width of the R. They differ only in that *Pachylocrinus* has two PBrr while *Abrotocrinus* has only one. *Abrotocrinus* usually has a pentagonal column in the proximal part while *Pachylocrinus* has a round column throughout its length. *Hylodecrinus* (Kirk, 1941) has stout endotomous arms like *Abrotocrinus* but has two PBrr like *Pachylocrinus*.

ABROTOCRINUS sp.
Plate 65, figs. 29–31

The genus *Abrotocrinus* is represented by several incomplete specimens in the Banff fauna, none of which is complete enough to allow for close comparisons with other species. Several specimens are figured for stratigraphic value.

The cup is robust suggesting a stout, heavily armed form. Cup low, bowl-shaped, IBB small, only tips projecting from beneath column. BB slightly globose. RR wider than high, height 2.9 mm., width 6.3 mm. A deep, round pit occurs at each plate corner. Low folds mark the surface of RR and BB plates for a short distance on either side of the suture. These same folds cross the suture from one R to the adjoining R. All XX plates are marked in the same manner. On one specimen sinuous interlocking sutures mark BB, RR, and XX plates, suggesting slight mobility.

RA, X, and RX in normal position, plate corners depressed giving them a stellate appearance.

PBrr one, occupying full width of R, suture relatively straight, wider than high, slightly constricted at mid-length. SBrr four to five, stout, non-cuneiform, all arms incomplete.

Remarks.—This large species of *Abrotocrinus* probably is new. The bulbous BB plates suggest relationships to *A. cymosus* Miller and Gurley, the genotype. The small folds between basal and radial plates are not known on other species.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9927, 9928, 9929.

Genus DINOTOCRINUS Kirk, 1941

The genus *Dinotocrinus* was erected for late Mississippian (Meramec and Chester) inadunate crinoids with a broadly expanding, somewhat rounded cup with the IBB not showing on the lateral wall, a single PBrr, with the arms branching only once above the PBrr, and a relatively short crown. The genus appears to be closely related to some of the more primitive forms of the Zeacrinitidae. *Dinotocrinus* is somewhat more distantly related to *Ascetocrinus* but lacks the long slender crown and arms that branch more than once above the PBrr. *Dinotocrinus* is also distantly related to *Ampelecrinus* but lacks the conical cup with the IBB showing on the lateral wall.

The single specimen referred to *Dinotocrinus* in the Banff fauna does not have the rounded cup that characterizes the genus. Instead the cup is widely flaring, but definitely conical and not rounded. The IBB are very small and only the points project beyond the column. In general it appears to lie somewhere between *Ampelecrinus* and *Dinotocrinus* in its evolutionary development. The conical cup resembles the cup of *Ampelecrinus*, but flares much more widely, and the IBB are smaller. The arms branch only once above the PBrr, as in *Dinotocrinus*, and the beginnings of the truncated base seen in *Dinotocrinus* are present.

The specimen is referred tentatively to *Dinotocrinus* with full understanding that it may be necessary to revise the assignment at a later date when more information is available.

DINOTOCRINUS ALBERTAENSIS n. sp.
Plate 65, fig. 32; plate 69, fig. 5

Crown compact, relatively short, ex-

panding slightly at about mid-length and recurving at tips of arms.

Cup broadly flaring, truncated at base, height 2.1 mm., width at arm bases 5.7 mm. Plates smooth, not arcuate or stellate, corners and sutures not depressed.

IBB small, entirely hidden beneath the column apparently in a slight concavity. BB small, making up lower lateral cup wall. PB larger than others. RR wider than high, width 2.3 mm., height 1.3 mm., facets essentially straight, occupying full width of R. RA large, in normal position on PB and RPB, laterally in contact with X and RAR, and beneath Rt. X visible in part, approximately the same size as RA, in normal position on truncated upper surface of PB.

PBrr one, except in A ray where there are five. PBrr slightly constricted at mid-length, each marked with small papillae. PBr_1 in A ray longer than others, facet directed obliquely toward R anterior ray. SBrr six in each of two arms available for observation, arms not branching above SBrr. TBrr at least 14. Pinnule facets directed obliquely upward from marked lateral projection of Br. Axis of each Br curved slightly toward pinnule facet giving rise to zigzag appearance common in *Decadocrinus*. Pinnules stout, very long, reaching nearly full length of arms, having an acuminate ridge giving them roughly a triangular appearance.

Sac not available for study, not projecting beyond arms.

Column round, slender.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass, Alberta.

Types.—Holotype GSC No. 9930.

Genus PACHYLOCRINUS Wachsmuth and Springer, 1880

PACHYLOCRINUS sp.
Plate 65, fig. 34

A single cup with a few of the lower arm brachials attached is the only Banff specimen referable to *Pachylocrinus*. It is figured for stratigraphic value. The cup is bowl-shaped, the IBB are small, barely appearing on the lateral cup wall, the R facets occupy the full width of the R. X and RA are in the normal position and there are two PBrr.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9931.

Genus HYLODECRINUS Kirk, 1941

This genus was separated from species that would normally be referred to *Pachylocrinus*. *Hylodecrinus* is characterized by relatively few bifurcations of the arms and a long sac. The arm brachials of *Hylodecrinus* are relatively more markedly cuneiform than those of *Pachylocrinus*. We doubt if there is valid reason for separation of this genus from *Pachylocrinus*.

HYLODECRINUS sp.
Plate 65, fig. 35

This specimen is referred to *Hylodecrinus* mainly because of the length of the crown and the relatively few divisions of the arms. The brachials of the arms are not cuneiform and resemble those found in *Pachylocrinus* far more than *Hylodecrinus*.

Crown long, slender, apparently expanded at mid-length and recurved at arm tips.

Cup low, bowl-shaped, truncated at base. IBB small, hidden beneath column. R facets occupy full width of upper surface of R. PBrr two, arms branch at least once and perhaps twice above primary dichotomy. Brachials not cuneiform. Column and sac unknown.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9931.

ZEACRINITIDAE Moore and Laudon, 1943

Genus LINOCRINUS Kirk, 1938

LINOCRINUS FACULENSIS n. sp.
Plate 65, fig. 16; plate 69, fig. 6

The characters of *Linocrinus* were manifested early in Mississippian history and retained their identity throughout the period. *Linocrinus* shows close relationships to *Decadocrinus* and particularly to *Pelecocrinus* because of its keeled, specialized arm brachials. The low bowl-shaped cup is also present in all three genera. The open arm structure and restricted R facets of *Pelecocrinus* separate it immediately from *Linocrinus*. The single dichotomy in the arms of *Decadocrinus* separate it readily from the multiple branching arms of *Linocrinus*.

Linocrinus is represented by a single specimen in our collections from the Banff formation. Because this marks one of the earliest known occurrences of the genus, we

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are describing it although it is incompletely known.

Crown expanding slowly to the mid-length, then rapidly and recurving at the arm tips, 35 mm. in length.

Cup broadly expanding, low, bowl-shaped, widest at arm bases, height 2.4 mm., width 9.4 mm.

IBB small, only tips project from beneath column. BB slightly higher than wide. RR wider than high, width 3 mm., height 1.9 mm. R facets occupy full width of R. RA and X not available for observation. Plates with sharp keel ridges, corners depressed.

Arms endotomous except in anterior ray where they are isotomous, branching at least twice above primary dichotomy. PBrr one, except in anterior ray where there are four, conspicuously constricted at mid-length, facets directed obliquely separating higher brachials as in *Pelecocrinus*. SBrr six, except in anterior ray where there are from eight to eleven, facets of axillary SBrr obliquely directed separating higher Brr. Upper portion of arms long, delicate, slender. All Brr in lower portion of arms sharply keeled, facets directed obliquely upward from conspicuous lateral projections of upper surface of Brr, only very slightly cuneiform. Brr of upper arms essentially quadrate, without conspicuous keels, markedly different from Brr of lower arms. Pinnules slender, directed obliquely upward.

Sac not known.

Column round.

Remarks.—Linocrinus faculensis differs from other known species in its more delicate arms, its remarkably strongly keeled Brr in the lower arms passing into simple quadrate Brr in the upper arms. It contrasts sharply with *L. compactus* (Laudon), the other known Kinderhook form, in which the Brr are essentially non-keeled.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass Area, Alberta.

Types.—Holotype GSC No. 9933.

SCYTALOCRINIDAE Moore and Laudon, 1943

Genus DECADOCRINUS Wachsmuth and Springer, 1879

DECADOCRINUS BRAZEAUENSIS n. sp.

Plate 65, figs. 36–38; plate 69, fig. 7

The name *Decadocrinus* is being retained for inadunate crinoids with a low, widely flaring cup, three anals in cup, two Brr, and two sinuous, keeled, unbranched arms to each ray that bear strong ramules on alternate sides, one from each Br.

A single species of *Decadocrinus* closely related and perhaps ancestral to *D. baumgardneri* Laudon and Beane (1937, p. 258) occurs in the Banff fauna. The Banff species is also closely related to *D. scalaris* (Meek and Worthen) (1869, p. 145), the genotype, from which it differs by having a markedly more sinuous arm pattern and less robust Brr. *D. brazeauensis* is represented in our collections by three excellently preserved specimens in which essentially all of the characters are available for study.

Crown expanding only slightly and recurved at arm tips, length in holotype 26 mm.

Cup expanding rapidly, moderately conical, height in holotype 2.4 mm., width at arm bases 4.8 mm., all cup plates marked with low stellate ridges, corners deeply depressed, surface finely papillose. IBB small, projecting only slightly beyond column. BB slightly globose, width on

EXPLANATION OF PLATE 66

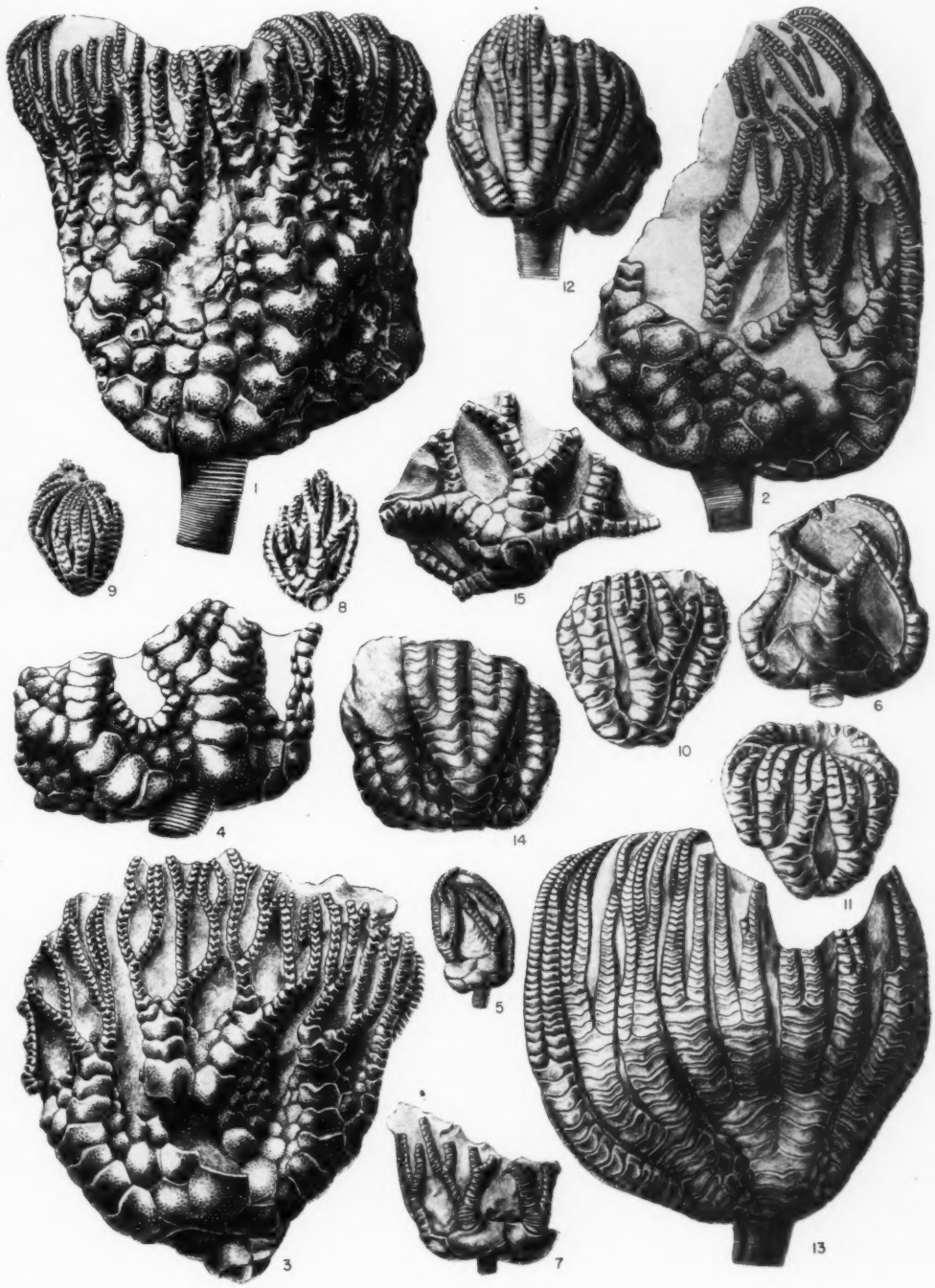
FIGS. *1–4—Forbesiocrinus withersi* Laudon, Parks and Spreng, n. sp. *1*, holotype, posterior view, GSC 9939; *2*, paratype, posterior view, GSC 9940; *3*, paratype, posterior view, GSC 9941; *4*, paratype, left posterior view, GSC 9942. (p. 559)

5–7—Nipterocrinus wachsmuthi Meek and Worthen. *5*, lateral view, GSC 9943; *6*, lateral view, GSC 9944; *7*, lateral view, GSC 9945. (p. 559)

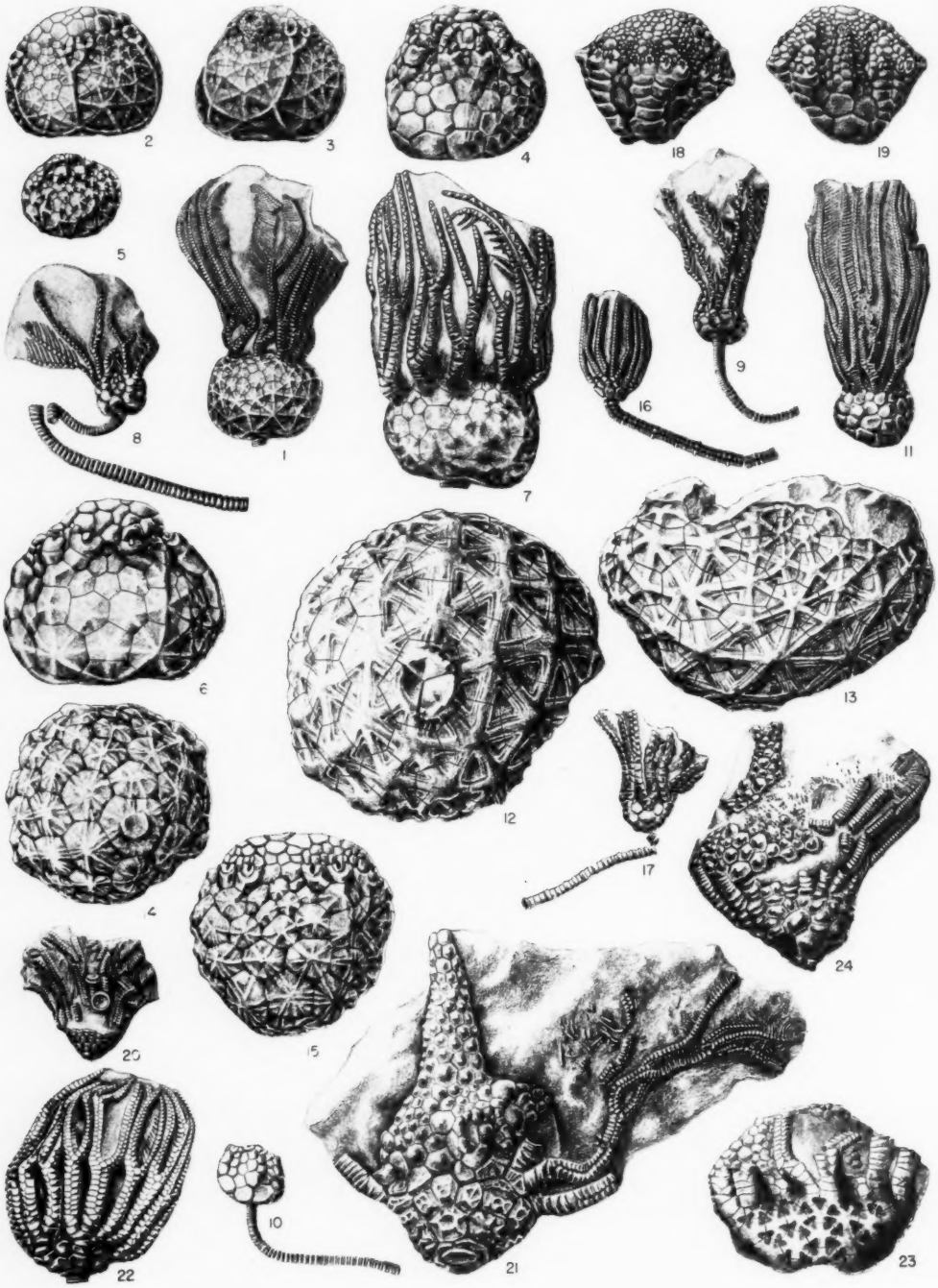
8, 9—Eutaxocrinus pulvinatus Laudon, Parks and Spreng, n. sp. *8*, holotype, right anterior view, GSC 9946; *9*, holotype, left posterior view, GSC 9946. (p. 560)

10–14—Paraichthyocrinus seversoni Laudon, Parks and Spreng, n. sp. *10*, paratype, left posterior view, immature specimen, ×2, GSC 9950; *11*, paratype, right anterior view, immature specimen, ×2, GSC 9950; *12*, holotype, left anterior view, GSC 9947; *13*, paratype, lateral view, GSC 9949; *14*, paratype, right anterior view, GSC 9948 (p. 560)

15—Onychocrinus sp., left anterior view, GSC 9951. (p. 561)



Laudon, Parks and Spreng, Mississippian Crinoids from Canada



Laudon, Parks and Spreng, Mississippian Crinoids from Canada

holotype 1.7 mm., height 1.9 mm. RR wider than high, width 2.1 mm., height 1.3 mm., low stellate ridges radiate to adjacent RR and downward to BB. Facets arcuate, occupying considerably more than half of upper surface of R, suture gaping. RA slightly smaller than BB in normal position. X smaller than RX, in normal position on truncated upper surface of PB.

Arms not branching above primary dichotomy, remarkably sinuous in appearance. PBrr two, second much longer than first, facets of PBr_2 obliquely directed separating higher Brr, papillose surface of cup plates extended to lower Brr of arms. SBrr all sharply keeled with the main axis curved and bifurcating at junction with ramule axis. Ramule facets arising from abruptly projecting portions of each Br, directed approximately 80 degrees from the main axis of the arms. Ramules stout, short.

Column round, of alternately expanded columnals in the proximal portion. Columnals of equal weight in lower part of column.

Remarks.—*D. brazeauensis* differs from *D. baumgardneri* and *D. scalaris*, its nearest relatives, in having a more sinuous arm pattern, relatively less robust arm Brr, weakly stellate plate markings with delicate papillose markings.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9934; paratypes GSC Nos. 9935, 9936.

RAMULOCRINUS n. gen.

Genotype.—*Ramulocrinus nigelensis*, n. sp.

The Scytalocrinidae had their origins in the primitive Ottawacrinidae and were well established as a family in the Devonian. With a form related to *Cradeocrinus* as an ottawacrinid ancestor; the development of the Scytalocrinidae demanded only the development of pinnules on all of the brachials. The species now classed under *Decadocrinus* in Devonian rocks are examples of primitive scytalocrinids. The main trends of scytalocrinid evolution are forecast in the Devonian species. Species with smooth arms and quadrate brachials such as *D. killawogensis* Goldring eventually gave rise to the smooth armed forms of the Mississippian such as *Scytalocrinus*. Another Devonian group represented by such species as *D. nereus* (Hall) and *D. multinodosus* Goldring developed the beginnings of the sinuous zigzag arm found in Mississippian species of *Decadocrinus* and the new genus *Ramulocrinus*. Devonian decadocrinids all have two PBrr while both *Scytalocrinus* and the new genus *Ramulocrinus* have developed a single PBr by fusion of the two original PBrr.

The name *Decadocrinus* is being retained for inadunate crinoids with a widely expanding cup, two PBrr, the arms not branching beyond the primary dichotomy, and the characteristic sinuous zigzag arm brachials. *Histocrinus*, having two PBrr, is

EXPLANATION OF PLATE 67

FIGS. *1–6*—*Rhodocrinites brewsteri*, Laudon, Parks and Spreng, n. sp. *1*, holotype, lateral view, GSC 9952; *2*, paratype, anterior view, ×2, GSC 9955; *3*, paratype, posterior view, ×2, GSC 9955; *4*, paratype, left anterior view, ×2, GSC 9956; *5*, paratype, posterior view, GSC 9953; *6*, paratype, anterior view, ×2, GSC 9954. (p. 561)

7—*Rhodocrinites pantheri* Laudon, Parks and Spreng, n. sp., holotype, posterior view, GSC 9957. (p. 562)

8, 9—*Rhodocrinites cirrusi* Laudon, Parks and Spreng, n. sp. *8*, paratype, lateral view, ×2, GSC 9959; *9*, holotype, lateral view, ×2, GSC 9958. (p. 563)

10, 11—*Cribanocrinus wilsoni* Laudon, Parks and Spreng, n. sp. *10*, paratype, lateral view, immature specimen, ×2, GSC 9961; *11*, holotype, lateral view, GSC 9960. (p. 563)

12–15—*Maligneocrinus medicinensis* Laudon, Parks and Spreng, n. sp. *12*, holotype, basal view, GSC 9962; *13* holotype, anterior view, GSC 9962; *14*, paratype, basal view, GSC 9963; *15*, paratype, posterior view, GSC 9963. (p. 566)

16, 17—*Aorocrinus iola* Laudon. *16*, lateral view, GSC 9968; *17*, lateral view, ×2, GSC 9969. (p. 569)

18, 19—*Aorocrinus banffensis* Laudon, Parks and Spreng, n. sp. *18*, holotype, anterior view, GSC 9966; *19*, holotype, posterior view, GSC 9966. (p. 568)

20—*Aorocrinus* sp., lateral view, GSC 9967. (p. 569)

21–23—*Sunwaptacrinus brazeauensis* Laudon, Parks and Spreng, n. sp. *21*, holotype, posterior view, GSC 9970; *22*, paratype, lateral view, GSC 9971; *23*, paratype, lateral view, GSC 9972. (p. 570)

24—*Eretmocrinus tentor* Laudon, lateral view, GSC 9973. (p. 570)

an offshoot from the smooth-armed Devonian forms. Reduction of the double PBrr to a single PBr gave rise to such Mississippian genera as *Phacelocrinus*, *Hypselocrinus*, and *Scytalocrinus* among the smooth-armed forms. *Scytalocrinus* or a closely related form is the probable ancestor of a long line of late Mississippian and Pennsylvanian crinoids now classed in the Erisocrinidae.

The new genus *Ramulocrinus* is being established for inadunate crinoids with a widely flaring cup, three anals in cup, arms not branching beyond the primary dichotomy, a single PBr, and the arms having the characteristic sinuous, zigzag appearance of their immediate ancestor *Decadocrinus*. *Ramulocrinus* is thought to have developed from the sinuously armed Devonian decadocrinids in the same manner that *Scytalocrinus* developed from the smooth-armed Devonian decadocrinids, by reduction of the double PBrr to a single PBr.

RAMULOCRINUS NIGELENSIS n. sp.
Plate 65, figs. 39–40; plate 69, fig. 8

Crown expanding only slightly, apparently recurved little. Length of holotype 32 mm.

Cup low, rapidly expanding, moderately steep to tops of BB with RR flaring widely. Height of cup in holotype 2.9 mm., width at arm bases 7 mm. IBB small, curving around to make a definite, but relatively minor, part of the lateral wall, definitely not covered by column. BB small, height equals width, obscurely stellate, directed almost vertically. The IBB and BB form a low rounded cup and the RR flare abruptly laterally from the tops of the BB. RR wider than high, width 2.5 mm., height 1.2 mm., low ridges radiate downward to BB occupying full width of R, suture gaping. Facet remarkably straight in contrast to the somewhat curving facet of *Decadocrinus*. RA in normal position, X not available for observation.

Arms not branching beyond primary dichotomy, having characteristic zigzag *Decadocrinus*-appearance. PBrr one, markedly constricted at mid-length, unusually long, sharply keeled, facets laterally directed separating higher Brr. All Brr long, sharply keeled, with keel rising to an acuminate node immediately below the succeeding Br suture. Sutures markedly cuneiform, axis of keel curving to meet cuneiform facet in middle, giving rise to the sinuous appearance of the arms. Ramules long, stout, considerably less robust than is normal for *Decadocrinus*.

Sac rounded, stout, rising almost full length of arms, surmounted with a long spine.

Column unknown, impression of proximal columnal on holotype appears to be pentagonal.

Remarks.—*Ramulocrinus nigelensis* is closely related to *R. bozemanensis* (Miller and Gurley) from the Lodgepole formation of Montana. *R. bozemanensis* has a more steeply conical cup, less markedly cuneiform arms, and lacks the sudden expansion of the cup at the tops of the BB. *R. nigelensis* is distantly related to *R. albertsi* (Miller and Gurley) from the Chester of Illinois. *R. albertsi* has a very broadly expanded cup and the IBB do not show on the lateral wall. *R. nigelensis* is distantly related to *R. repertus* (Miller and Gurley) from the Keokuk beds of Indiana. *R. repertus* differs in having shorter Brr and a tendency toward stellate plate markings.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Type.—Holotype, GSC No. 9937; paratype GSC No. 9938.

SAGENOCRINITIDAE Bassler, 1938
Genus FORBESIOCRINUS de Koninck and le Hon, 1854

The discovery of excellently preserved specimens of *Forbesiocrinus* in rocks of Kinderhook age in America is unusual. *Forbesiocrinus* occurs in rocks of earliest Lower Carboniferous age in Belgium in the limestone of Tournai. Yet all American species known to date have been collected from rocks ranging in age from Upper Burlington to Warsaw. The occurrence of *Forbesiocrinus* in rocks of Banff age marks the oldest occurrence of this genus in America.

It is even more interesting that the Banff species compares very closely with *F. nobilis* de Koninck and le Hon, the Tournai species.

Little can be added here to the scholarly masterpiece of Springer (1920, p. 225)

concerning the origin, evolution, and classification of *Forbesiocrinus*. Early confusion that had arisen over the relationships of *Forbesiocrinus* to the Taxocrinidae was dispelled by a thorough elucidation of the affinities of *Forbesiocrinus* with the Sagenocrinitidae and not the Taxocrinidae.

FORBESIOCRINUS WITHERSI n. sp.
Plate 66, figs. 1–4; plate 69, fig. 9

This species is represented by several excellently preserved specimens in our collections. It is named in honor of Mr. Peter Withers, Jasper, Alberta, whose constant efforts on behalf of our field party during our work in the Sunwapta Pass area contributed greatly to its success.

Crown obscurely pentalobate, expanding gradually and recurved at the tips of the arms. The holotype is slightly over 60 mm. in height up to the point where the arms curve abruptly inward.

IBB small, completely hidden by the column. BB small, except PB, laterally directed, only tips appearing beyond column. PB unusually large rising to more than half the height of the RR. RR large, width on holotype 9.2 mm., height 7.1 mm., arched to form the beginning of a conspicuous ray ridge. PBrr three, arched to form ray ridge, as large as RR. SBrr three, slightly smaller than PBrr, width of SBr_3 7.8 mm., height 5.7 mm. TBrr four or five, tapering rapidly in size, width of TBr_4 3.1 mm., height 2.2 mm. 4Brr between five and thirteen, small, width averages 1.4 mm., height less than 1 mm. The arms curve inward shortly above the axillary 4Br. At least one more bifurcation is developed on some of the arms. Interbrachials numerous, in angular articulation with the Brr, ending in an arcuate nodose rim at the point of connection to the peristome. Highest point of articulation is SBr_3. This brim-like margin of iBrr plates led early workers to class *Forbesiocrinus* with *Onychocrinus* of the Taxocrinidae. *F. nobilis*, the genotype, has very few iBrr plates and and all previously known American species have many iBrr. *F. withersi* lies mid-way between *F. nobilis* and the younger American forms as far as development of iBrr plates is concerned. Both iSBr and iTBr plates are present.

The posterior interradius differs little from other iBrr areas. The PB rises high on the lateral cup wall well over half of the height of the RR. RA is in sutural contact with the truncated upper right surface of PB, followed upward by a row of three plates. This row of X plates is in sutural contact with normal iBrr plates.

Column expanded proximally, of thin columnals, alternately expanded in proximal area.

All plates up to the top of the TBrr including X and iBrr plates are strongly pustulose. Pustules tend to be arranged in vertical rows in the upper arm brachials, giving the appearance of ridges on all of the higher Brr.

Remarks.—*F. withersi* has pustulose plates apparently identical with *F. nobilis*. It differs from *F. nobilis* in having many more iBrr. It tends to have the pentalobate shape, and the raised ray ridges of *F. agassizi* Hall, its next closest relative. It differs from *F. agassizi* and all other younger American species in having far fewer iBrr.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9939; paratypes GSC Nos. 9940, 9941, 9942.

HOMALOCRINIDAE Angelin, 1878
Genus NIPTEROCRINUS Wachsmuth, 1868
NIPTEROCRINUS WACHSMUTHI Meek and Worthen
Plate 66, figs. 5–7

Three specimens of *Nipterocrinus* tentatively referred to *N. wachsmuthi* Meek and Worthen are present in our collections. The genus *Nipterocrinus* as known up until now has been found only in the Burlington limestone and in the basal beds of the Keokuk formation. Its presence in the Banff formation in beds of Kinderhook age extends the range of the genus. *Nipterocrinus* is considered to have evolved from *Pycnosaccus* (Springer, 1920, p. 201). The general form of the crown of *Nipterocrinus* was already attained in *Pycnosaccus welleri* Springer (Silurian, Tennessee). *P. welleri*, however, retains the primitive radianal and X plates and thus does not develop perfect pentamerous symmetry. *Nipterocrinus*, with no RA and X plates is a normal end product of evolution among flexible crinoids.

Primitive species of *Pycnosaccus* have one or two PBrr and *P. welleri* has two, three, and rarely four PBrr. In primitive species of *Pycnosaccus* relatively few SBrr are found while in *P. welleri* three to six SBrr are present. This would seem to indicate that additional Brr in the lower parts of the arms indicate more advanced evolutionary stages in *Nipterocrinus*.

The type of *Nipterocrinus wachsmuthi* (Springer, 1920, pl. 15, fig. 1a) is characterized by three unusually short PBrr. One of the specimens figured as *N. wachsmuthi* (fig. 2a, 2b) has four PBrr that are conspicuously higher than the PBrr of the holotype. Two of our Canadian specimens resemble the specimen figured in figures 2a and 2b (Springer, 1920, pl. 15) and one has only three PBrr and resembles the holotype somewhat more closely. It seems probable that revision of the species *N. wachsmuthi* by close comparison might lead to desirable subdivision.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9943, 9944, 9945.

TAXOCRINIDAE Angelin, 1878

Genus EUTAXOCRINUS Springer, 1906

EUTAXOCRINUS PULVINATUS n. sp.

Plate 66, figs. 8–9; plate 69, fig. 10

Eutaxocrinus pulvinatus is represented by a single specimen in our collections. The cup is high, not rapidly expanding and the crown is narrow, not flaring. The general stage of evolution lies between *E. ithacensis* (Williams) (Upper Devonian) and *E. fletcheri* (Worthen) (Kinderhook, LeGrand, Iowa).

IBB low, but definitely forming a part of the wall of the cup. BB erect, only slightly wider than high, posterior higher and wider than others. RR in lateral contact except at posterior, width 4 mm., height 2 mm., broadly rounded. PBrr two, first 3.5 mm. in width, 2 mm. in height, second axillary, slightly smaller. SBrr variable from three to five, ASBr five RASBr, LASBr, and LPSBr with four, RPSBr with three. Width averages 2 mm., height 1.2 mm. SBrr variable from five to as many as nine and variable on opposite sides of the dichotomy. PB large, elongated, notched for X plate. All X plates except one missing. A single small plate, an apparent remnant of the X series, occurs at the right side of the area but is not in contact with PB. No iBrr plates in crown. A single thin columnal is attached to IBB.

Remarks.—*E. pulvinatus* can be differentiated from *E. ithacensis* its nearest relative, in that the crown of *E. pulvinatus* is larger, more flaring, and the lower brachials are more robust. The structure is identical except perhaps for the upper arms.

E. nigelensis is much more primitive than *E. fletcheri* from the Hampton beds at LeGrand, Iowa, in that it lacks the iBrr plates, the IBB are higher, and the crown is less flaring and the arms shorter.

Occurrence.—Banff formation, upper crinoid zone. Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9946.

Genus PARAICHTHYOCRINUS Springer, 1902

PARAICHTHYOCRINUS SEVERSONI n. sp.

Plate 66, figs. 10–14; plate 69, fig. 11

The occurrence of *Paraichthyocrinus* in beds of Kinderhook age, heretofore known only from the Burlington and Keokuk, marks the earliest known occurrence of the genus. The main characteristics of the genus are its closely abutting arms above the iBrr, its short crown, weakly developed anal area, and IBB outside BB ring appearing as a columnal. *P. seversoni* n. sp. represents an unusually advanced stage of evolution in that the anal and iBrr areas are most closely to be compared to *P. crawfordsvillensis* (Miller and Gurley) from the Keokuk formation. The slightly elongated PB is followed by X and well developed bordering plates are present on the right. The iBrr are strongly developed with six or seven plates commonly being present in at least four ranges.

IBB three, projecting below BB as ring, appearing as a columnal, not included in BB circle. BB five, small, laterally directed with tips curved upward outside IBB ring. PB slightly larger, truncated at contact with X and at right of first bordering tube plate. RR five smaller than PBr, both right and left RR smaller than others because of enlarged PB. PBrr three, gradually enlarging upward. PBr_1 larger than R, width 7 mm., height 2.5 mm. PBr_3 width 9 mm., height 3 mm., in contact laterally with

third range of iBrr. SBrr four, broad, rounded, arched very little, first three closely abutting, fourth separated on inside of ray by a single, small iSBr. iBr_4 slightly less wide than iBr_3 due to SBr plate. SBr_2 width 9 mm., height 3 mm., SBr_4 width 8 mm., height 3 mm. TBrr four to six, broad, arched little, lower two or three closely abutting on inside of ray. TBr_5 width 5 mm., height 2 mm. Arms not closely abutting above TBrr, width of Brr decreases rapidly, one or two more bifurcations at variable positions in arms. Arms incurving and slender at tips.

Surface essentially smooth.

Column expanded proximally, of closely packed columnals.

Remarks.—Two specimens, (Plate 66, figs. 10–11 and 12), here tentatively referred to *Paraichthyocrinus seversoni*, may eventually be determined to be not even referable to *Paraichthyocrinus*. Both are assumedly immature individuals and are without iBrr. We are of the opinion that iBrr would be developed in an individual approaching as near to maturity as the specimen shown in fig. 12. In this specimen the crown is short, the arms are infolded and the arms are relatively closely abutting as in *Paraichthyocrinus* but the complete lack of iBrr throws doubt on assignment to *Paraichthyocrinus*.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9947; paratypes GSC Nos. 9948, 9949, 9950.

Genus Onychocrinus Lyon and Casseday, 1860
Onychocrinus sp.
Plate 66, fig. 15

If this single, somewhat fragmentary specimen is correctly referred to *Onychocrinus*, then it is the oldest known representative of that genus. *Onychocrinus* is first known from rocks of Lower Burlington age. The widely expanded cup and laterally directed, rounded arms with three PBrr would be expected in the most primitive species to be referred to this genus. The elongated PB with a typical taxocrinid X plate is plainly visible.

We are not proposing a specific name because of the incomplete, single specimen. It is figured for stratigraphic value and whatever evolutionary value it may eventually be determined to have.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9951.

Rhodocrinitidae Bassler, 1938
Genus Rhodocrinites Bassler, 1938

Three species of *Rhodocrinites*, all described as new, all relatively closely related, and all more primitive than any of the known species from the LeGrand, Iowa beds or the Gilmore City, Iowa beds, are found in the Banff fauna. The ancestral, more primitively developed characteristics of several of the younger Kinderhook species of *Rhodocrinites* are found in the Banff species. The Banff species have uniserial, cuneiform to weakly biserial arms while all of the later species have well-developed biserial arms. The arms of the Banff species branch more than once and high above the calyx while all later species branch relatively close to the cup. The tegmen of the Banff species is very much restricted in size in comparison to the total width of the cup and is not markedly pentagonal in outline as characterizes many of the later species.

Rhodocrinites brewsteri is the most advanced of the Banff species and is definitely ancestral to the very abundant *R. douglassi* Miller and Gurley group that characterizes the Gilmore City formation of Iowa. It has the stellate plates and the beginning of a basal concavity which are so well developed on all members of the *R. douglassi* group. It differs markedly from all of the species in the *R. douglassi* group in that the tegmen is much more markedly constricted in *R. brewsteri*, the arms are slender, branch the second time at a much greater distance from the cup, and are only weakly biserial.

Rhodocrinites brewsteri n. sp.
Plate 67, figs. 1, 2, 3, 4, 5, 6; plate 69, fig. 12

Crown constricted at arm bases, arms expanding and recurved at tips, height of holotype 38 mm.

Dicyclic, cup subglobular, constricted at arm bases, IBB confined to moderately developed basal concavity, holotype maximum width 17 mm., height to arm bases 11

mm. BB five, laterally directed at junction with basal concavity, curved upward to form conspicuous part of wall, width 5 mm. in holotype, height 4.5 mm., heptagonal, supporting primary iBr directly above. RR five, separated all around, heptagonal, width 4.5 mm., height 4.5 mm. PBrr two, first hexagonal, second pentagonal. Height equals width in both, first 3.5 mm., second 2.5 mm. SBrr two, followed by arms. Primary iBr rests on truncated upper surface of B, pentagonal, height in holotype 3 mm., width 2.5 mm., followed by 2, 3, 3, 3 in the higher ranges. Interbrachial area constricts rapidly toward arm bases. PB followed directly by X which is larger than primary iBr. X followed by four small plates in next range. Anal area more broadly differentiated than iBrr areas, constricted, but not as markedly constricted as iBrr areas at arm level. Plates of anal area small, primitive.

Tegmen primitive, small, very markedly constricted, subpentagonal in outline, not spinose, plates moderately advanced in stage of evolution, neither few and large, nor small and numerous as is common in the more primitive ancestors of *Rhodocrinites*. Anus eccentric towards posterior, surrounded by small plates and opening through low pyramid.

Arms relatively delicate and slender, length 17 mm. in holotype, primitive for *Rhodocrinites*, representing a stage of evolution mid-way between cuneiform and biserial, branching somewhat variable, first bifurcation normally on second brachial but in one arm on holotype on fifth brachial. Second bifurcation high, as high as 18 brachials above first bifurcation. Arm preservation incomplete on holotype which apparently had eight arms to each ray in normal development. Pinnules arise from projections on brachial surfaces.

Remarks.—*R. brewsteri* is related to the *R. douglassi* stock that ranges abundantly throughout Kinderhookian rocks in North America. It can be readily distinguished from all other species in this stock, except the other more primitive Banff species, on the basis of its primitive arm brachials, the high, second bifurcation of the arms, and the primitive, constricted tegmen. Such forms as *R. douglassi*, *R. serpens* Laudon, *R. multidactylus* Laudon, *R. excavatus* Laudon, and *R. constrictus* Laudon from the Gilmore City formation of Iowa are all characterized by an advanced, expanded, flat-topped, large-plated tegmen. On all of the Gilmore City species, arm branching takes place a short distance above the cup and is much more definitely biserial.

R. brewsteri can be separated from *R. pantheri* in that *R. pantheri* is even more primitive in many respects than *R. brewsteri*. The arm brachials on *R. pantheri* remain completely cuneiform, there is no basal concavity, the tegmen is unusually small and primitive, and the second bifurcation of the arms is even higher than in *R. brewsteri*.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9952; paratype GSC No. 9953, 9954, 9955, 9956.

RHODOCRINITES PANTHERI n. sp.
Plate 65, fig. 7; plate 69, fig. 13

Rhodocrinites pantheri is found in the lower crinoid zone in the Banff formation in the Sunwapta Pass area in Alberta. This zone is some 120 feet stratigraphically below the upper crinoid zone in which *R. brewsteri* is found. *R. pantheri* is very closely related to *R. brewsteri* but slightly more primitive in part. It can be separated from *R. brewsteri* on the basis of its more primitive, entirely cuneiform arms, the higher second dichotomy in the arms, and the less well developed stellate markings on the cup.

The crown is slightly constricted at the arm bases, and the arms do not flare abruptly above the cup. The holotype is incomplete but measures 22 mm. in height and is estimated to be at least 27 mm. in total height.

Dicyclic, cup subglobose, markedly constricted at the arm bases. IBB five, small, not confined to a basal concavity. Holotype maximum width 12 mm., height to arm bases 5.5 mm. BB five, laterally directed and curving around to make a conspicuous part of the lateral wall, width 4 mm., height 3 mm., pentagonal. RR five, separated all around, heptagonal, width 4 mm., height 3.5 mm. PBrr two, first hexagonal, second pentagonal, axillary. SBrr two, followed by free arms. Primary iBr rests on

truncated upper surface of B, width 3 mm., height 2 mm., pentagonal followed by 2, 3, 3, 3, 2, 1 in the higher ranges.

Primary dichotomy in arms variable, on second to sixth Br. Second dichotomy high, ranging from ninth to fourteenth Br. First Brr above each dichotomy uniserial becoming cuneiform upward, never biserial. Pinnules short, slender.

Column unknown except for proximal columnals which are normal rhodocrinitid columnals.

Remarks.—*R. pantheri* is separated from *R. brewsteri* its next closest relative in the evolutionary scale on the basis of the more advanced weakly, biserial arms of *R. brewsteri*. It is separated from *R. cirrusi*, its closest, more primitive relative, on the basis of the much more primitive, essentially uniserial arms of *R. cirrusi* and the fact that the first dichotomy appears high in the arms of *R. cirrusi*.

Occurrence.—Banff formation, lower crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9957.

Rhodocrinites cirrusi n. sp.
Plate 67, figs. 8, 9; plate 69, fig. 14

This species of *Rhodocrinites* is the most primitive form known to us. It is represented by two specimens in our collections both of which retain the primitive ray ridges that characterized the more primitive ancestors of the Rhodocrinitidae. Both specimens have weakly developed stellate plate markings suggesting that they are ancestral to the *R. douglassi* (Miller and Gurley) group.

The crown is only slightly constricted at the arm bases; the arms are slender and essentially uniserial. Height of crown in holotype 13 mm.

The cup is globose, only slightly constricted at arm bases, height 3 mm., width 3.5 mm. IBB small, projecting only slightly beyond column, basal concavity if present very shallow. BB curving around to become conspicuous part of lateral wall, much larger than RR. RR pentagonal, separated all around. PBrr two, first quadrangular second pentagonal. SBrr one at most, with free arms arising directly from SBr_1. Primary iBr rests on truncated surface of B and followed by 2, 3, 1, plates in higher ranges. Posterior side not available for study.

When we first studied these specimens we assumed that they were immature individuals belonging to the species *R. pantheri*. Close study of the arms shows that they could not possibly be classed with *R. pantheri* or with any of the known younger Mississippian species. The arms are uniserial to very weakly cuneiform near the tips. The chief distinguishing feature is seen in the first dichotomy which is as high as 12 Br above the cup. The arms are slender, weak, and the pinnules are short.

The column is stout in comparison to the crown, consists of alternate thick and thin columnals, and the proximal columnals are much more closely spaced than those in the distal portion of the column.

Remarks.—This species is separated from all other known forms on the basis of its essentially uniserial arms and the high position of the first dichotomy.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9958; paratype No. 9959.

Genus Cribanocrinus Kirk, 1944
Cribanocrinus wilsoni n. sp.
Plate 67, figs. 10, 11; plate 69, fig. 15

This species of *Cribanocrinus* is represented by one excellently preserved specimen and one fragmentary, probably immature specimen that is provisionally referred to *C. wilsoni*.

The crown is constricted at the arm bases, the arms are slender and more than three times the height of the cup. Height of crown in holotype at least 38 mm.

Dicyclic, IBB small, in concavity. BB five, small, outer edges laterally directed. RR five, separated all around, width 3.9 mm., height 3 mm. in holotype. PBrr two, first quadrangular, smaller than B, width 2 mm., height 2.2 mm. in holotype; second heptagonal, axillary, width 4 mm., height 1.8 mm. in holotype. SBrr one followed by free arm plates. Ray ridges not developed, plates not stellate but slightly rounded, surface minutely pitted. Primary iBr, resting on truncated surface of B, as large as R, followed by 2, 2, 2 in the three following ranges. X plates not available for study.

Arms long, slender, branching three times, resulting normally in eight arms to each ray. Brachials in lower arms ornamented with short rugose spines on the exterior surface. Biserial brachials developed on second or third Br above cup. First dichotomy variable, between 10 and 15 Br above cup. Additional branching variable, with no single ray preserved completely. The inside arm does not branch above the first dichotomy, the outside arm of the next dichotomy does not branch again, and the inside branch of the second dichotomy bifurcates once again giving rise to four arms to each half of the ray. The right half of first described ray is variable in that the inside arm branches again above the first bifurcation. The pinnules are long, relatively slender, and laterally directed.

The column of the small specimen provisionally referred to *C. wilsoni* consists of alternately expanded columnals and the proximal columnals are thinner than the ones toward the distal end of the column.

Remarks.—The long, slender, multiple-branching arms, biserial immediately above the cup and ornamented with spines, indicate a relatively advanced stage of evolution for the genus *Cribanocrinus*. *C. watersianus* Wachsmuth and Springer, with two arms to the ray and uniserial arms for a considerable distance above the first dichotomy, can be considered as a primitive member of this genus. *C. wortheni* Hall with three arms to the ray and uniserial arms for some distance above the first bifurcation is the next stage of development. Such forms as *C. wachsmuthi* Hall and *C. wilsoni* exhibit the most advanced types of arm structure. *C. wilsoni* differs from *C. wachsmuthi* markedly in that *C. wachsmuthi* has uniserial arms to a considerable distance above the first arm bifurcation, lacks the spinose Brr, and has a more regular dichotomous arm branching pattern. The arms of *C. wachsmuthi* are more stout and shorter in comparison to the cup than the arms of *C. wilsoni*.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9960; paratype, No. 9961.

PERIECHOCRINITIDAE Wachsmuth and Springer

MALIGNEOCRINUS n. gen.

Genotype.—*Maligneocrinus medicinensis* n. gen., n. sp.

The genus *Maligneocrinus* is erected for a single variable species represented by a number of specimens whose ancestry,

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EXPLANATION OF PLATE 68

FIGS. *1–3*—*Athabascacrinus colemanensis* Laudon, Parks and Spreng, n. sp. *1*, holotype, anterior view, ×2, GSC 9964; *2*, holotype, basal view, ×2, GSC 9964; *3*, paratype, ventral view, ×2, GSC 9965. (p. 567)

4—*Cactocrinus imperator* Laudon, lateral view, GSC 9974. (p. 571)

5—*Cactocrinus arnoldi* (Wachsmuth and Springer), lateral view, GSC 9976. (p. 571)

6—*Cactocrinus* sp., lateral view, GSC 9978. (p. 571)

7–10—*Cactocrinus kuenzii* Laudon, Parks and Spreng, n. sp. *7*, holotype, lateral view, ×2, GSC 9979; *8*, paratype, posterior view, ×2, GSC 9981; *9*, paratype, anterior view, ×2, GSC 9981; *10*, paratype, lateral view, ×2, GSC 9980. (p. 572)

11—*Cactocrinus* sp., right anterior view, GSC 9977. (p. 571)

12–14—*Platycrinites sunwaptaensis* Laudon, Parks and Spreng, n. sp. *12*, holotype, lateral view, GSC 9982; *13*, paratype, lateral view, GSC 9983; *14*, paratype, lateral view, GSC 9984. (p. 573)

15—*Platycrinites* sp., lateral view, GSC 9988. (p. 574)

16—*Platycrinites* sp., lateral view, GSC 9989. (p. 574)

17, 18—*Platycrinites decadactylus* Laudon, Parks and Spreng, n. sp. *17*, holotype, lateral view, GSC 9985; *18*, paratype, lateral view, GSC 9986. (p. 573)

19—*Platycrinites* sp., lateral view, GSC 9987. (p. 574)

20—*Platycrinites* sp., lateral view, GSC 9990. (p. 574)

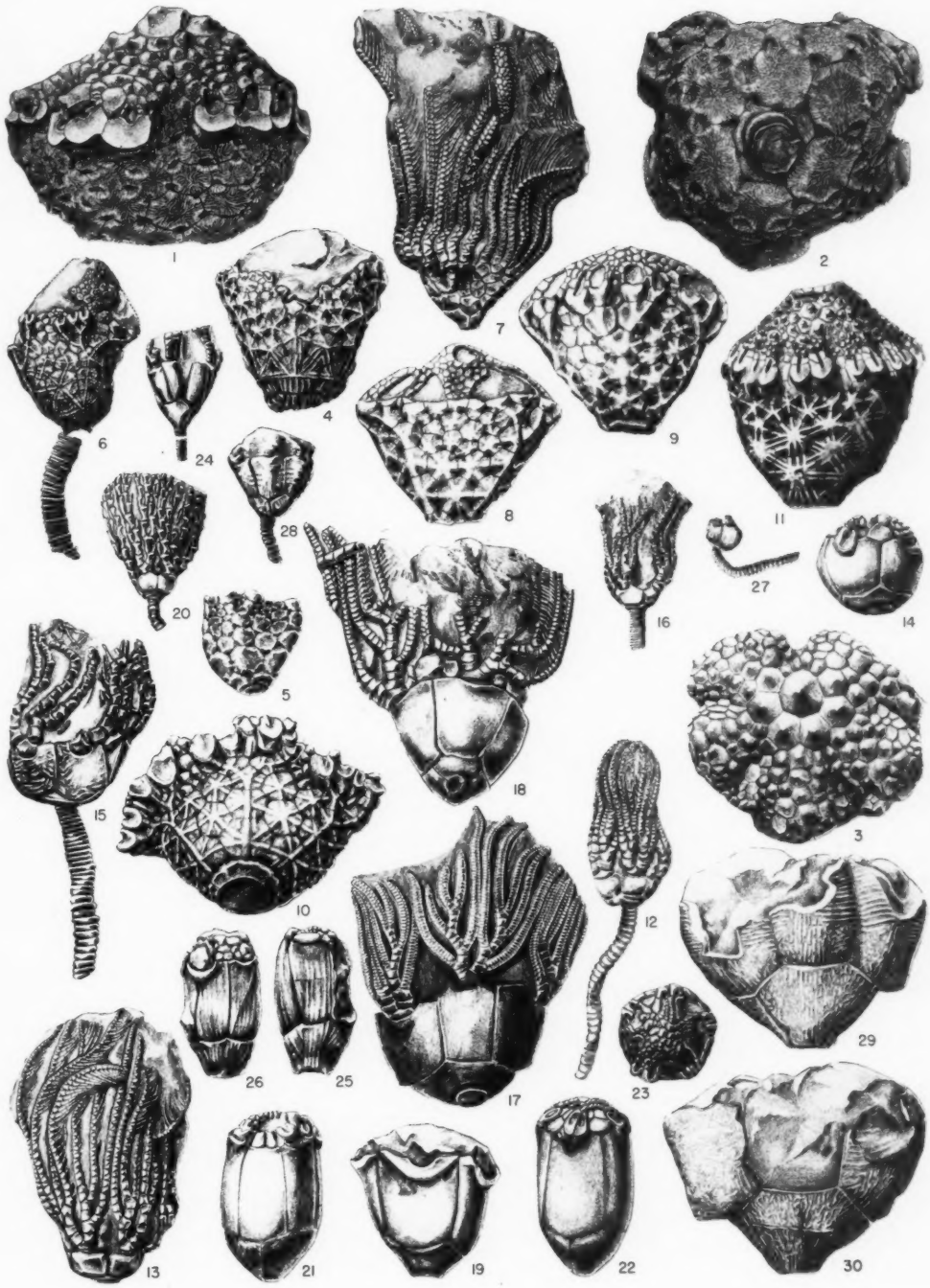
21–24—*Dichocrinus* sp. *21*, posterior view, GSC 9992; *22*, anterior view, GSC 9992; *23*, ventral view, GSC 9992; *24*, lateral view, GSC 9993. (p. 574)

25–26—*Dichocrinus* sp. *25*, right posterior view, GSC 9994; *26*, left anterior view, GSC 9994. (p. 575)

27—*Dichocrinus* sp., lateral view, GSC 9995. (p. 575)

28—*Dichocrinus bozemanensis* (Miller and Gurley), anterior view, GSC 9991. (p. 574)

29, 30—*Dichocrinus* sp. *29*, left posterior view, GSC 9996; *30*, right posterior view, GSC 9996. (p. 575)



Laudon, Parks and Spreng, Mississippian Crinoids from Canada

Laudon, Parks and Spreng, Mississippian Crinoids from Canada

though widely divergent, could have come only from some remote Devonian gennaeocrinid. Structurally it bears almost no relationship to known later Mississippian crinoids and hence must be considered as a specialized end product of evolution. Since it is a stellate-plated periechocrinitid with a broadly expanded cup, small tegmen plates, and the anus opening directly through the tegmen, its ancestry must be sought in the nearest, although very remotely related, Devonian ancestor, *Gennaeocrinus*.

Superficially some specimens of *Maligneocrinus* resemble dicyclic *Sphaerotocrinus* in external appearance, but no true relationship is indicated since *Maligneocrinus* is a monocyclic periechocrinitid. Several of the larger specimens have cup shapes and general appearance not unlike dicyclic *Thylacocrinus* with its broadly expanded, many plated cup, but again the resemblance is entirely superficial.

The cup of *Maligneocrinus* is large, very broadly expanded, and almost ball-shaped in adult specimens. The plates of the lower cup particularly are distinctively marked with multiple, stellate ridges.

The structure of the cup is related to

EXPLANATION OF PLATE 69

All illustrations on this plate are natural unretouched photographs.

FIGS. *1*—*Pelecocrinus banffensis* Laudon, Parks and Spreng, n. sp., holotype, left anterior view, GSC No. 9911. (p. 547)

2—*Pelecocrinus primordialis* Laudon, Parks and Spreng, n. sp., holotype, posterior view, GSC No. 9914. (p. 548)

3—*Cradeocrinus warreni* Laudon, Parks and Spreng, n. sp., holotype, posterior view, GSC No. 9915. (p. 551)

4—*Goniocrinus angulatus* Laudon, Parks and Spreng, n. sp., holotype, anterior view, GSC No. 9919. (p. 552)

5—*Dinotocrinus albertaensis* Laudon, Parks and Spreng, n. sp., holotype, right anterior view, GSC No. 9930. (p. 554)

6—*Linocrinus faculensis* Laudon, Parks and Spreng, n. sp., holotype, anterior view, GSC No. 9933. (p. 555)

7—*Decadocrinus brazeauensis* Laudon, Parks and Spreng, n. sp., holotype, anterior view, GSC No. 9934. (p. 556)

8—*Ramulocrinus nigelensis* Laudon, Parks and Spreng, n. sp., holotype, anterior view, GSC No. 9937. (p. 558)

9—*Forbesiocrinus withersi* Laudon, Parks and Spreng, n. sp., holotype, posterior view, GSC No. 9939. (p. 559)

10—*Eutaxocrinus pulvinatus* Laudon, Parks and Spreng, n. sp., holotype, right anterior view, GSC No. 9946. (p. 560)

11—*Paraichthyocrinus seversoni* Laudon, Parks and Spreng, n. sp., holotype, left anterior view, GSC No. 9947. (p. 560)

12—*Rhodocrinites brewsteri* Laudon, Parks and Spreng, n. sp., holotype, lateral view, GSC No. 9952. (p. 561)

13—*Rhodocrinites pantheri* Laudon, Parks and Spreng, n. sp., holotype, posterior view, GSC No. 9957. (p. 562)

14—*Rhodocrinites cirrusi* Laudon, Parks and Spreng, n. sp., holotype, lateral view, ×2, GSC No. 9958. (p. 563)

15—*Cribanocrinus wilsoni* Laudon, Parks and Spreng, n. sp. holotype, lateral view, GSC No. 9960. (p. 563)

16–18—*Athabascacrinus colemanensis* Laudon, Parks and Spreng, n. sp., *16*, holotype, basal view, GSC No. 9964; *17*, holotype, anterior view, GSC No. 9964; *18*, paratype, ventral view, GSC No. 9965. (p. 567)

19—*Aorocrinus banffensis* Laudon, Parks and Spreng, n. sp., holotype, posterior view, GSC No. 9966. (p. 568)

20, 21—*Sunwaptacrinus brazeauensis* Laudon, Parks and Spreng, n. sp. *20*, holotype, posterior view, GSC No. 9970; *21*, paratype, lateral view, GSC No. 9971. (p. 570)

22—*Cactocrinus kuenzii* Laudon, Parks and Spreng, n. sp., holotype, lateral view, GSC No. 9979. (p. 572)

23, 24—*Platycrinites sunwaptaensis* Laudon, Parks and Spreng, n. sp. *23*, holotype, lateral view GSC No. 9982; *24*, paratype, lateral view, GSC No. 9983. (p. 573)

25—*Platycrinites decadactylus* Laudon, Parks and Spreng, n. sp., holotype, lateral view, GSC No. 9985. (p. 573)

26—*Maligneocrinus medicinensis* Laudon, Parks and Spreng, n. gen. and n. sp., holotype, anterior view, GSC No. 9962. (p. 566)

periechocrinitids with three equal BB, RR five plus X, PBr_1 hexagonal, PBr_2 heptagonal, axillary, SBr_1 axillary and TBr_1 followed by free arms. The interbrachials are relatively large in the first three ranges, and small at the arm level. X followed by 2, 3, 4. Anal area more widely developed than iBrr areas. The fact that the X is followed by two instead of three plates shows definite advance in the stage of evolution of *Maligneocrinus* over all other periechocrinitids. The primitive hexagonal PBr_1 is retained because the X is less high than the RR. The arms are grouped, not lobate, and iBrr are broadly connected with the interambulacrals.

The tegmen consists of many small nonspinose plates, and the anal opening is unknown. The interambulacral areas are slightly depressed. The tegmen plates are larger in general than those of megistocrinids and approximately the same size as the tegmen plates of gennaeocrinids.

The arms and column are unknown.

Remarks.—*Maligneocrinus* is considered as related to *Gennaeocrinus* and not *Megistocrinus* because of its conical, broadly expanded cup, its stellate plate markings, and its relatively larger tegmen plates. No megistocrinids with stellate plates are known and it is assumed that they evolved from relatively smooth-plated periechocrinitids. Megistocrinids also inherited the primitive small-plated tegmen characteristics of the more primitive periechocrinitids.

Maligneocrinus is far removed from *Gennaeocrinus* of the Devonian but no other genus is even that closely related. It is probable that several forms transitional between *Gennaeocrinus* and *Maligneocrinus* will be found.

Occurrence.—All of the known specimens of *Maligneocrinus* in the Banff formation were found approximately 150 feet below the contact of the Banff formation with the overlying massive, gray limestone beds of the Dessa Dawn formation in the Maligne-Medicine Lake area in Jasper Park. The types were found high on the mountain east of Maligne River approximately one mile upstream from the confluence of Maligne River with Medicine Lake. They were found on the north slopes of the second steeply descending intermittent creek tributary to Maligne River.

Types.—Holotype, GSC No. 9962; paratypes, GSC No. 9963.

MALIGNEOCRINUS MEDICINENSIS n. gen. and n. sp.

Plate 67, figs. 12–15; plate 69, fig. 26

Known only from the dorsal cup and fragmentary portions of the tegmen. Arms and column are missing. The two specimens figured are widely different in gross cup shape and it is possible that two species should have been established. Several other partially complete specimens are in our collections and additional variation is present in them. The two specimens figured were chosen to represent the extremes.

Dorsal cup inflated, broadly rounded to almost ball-shaped, widest at arm bases. BB three, equal, forming a definite part of the cup wall although mainly directed laterally, excavated slightly for reception of proximal columnal. RR five plus X, in contact all around. Height 8 mm., width 14 mm. on holotype. PBrr two, large, hexagonal, height equals width, 9 mm. in holotype. SBrr one, axillary. TBrr one, followed by free arms. Primary iBr large, heptagonal, width 12 mm., height 11 mm. in holotype, followed by 2, 3, 5, 3, 2 in higher ranges, iBrr somewhat variable. X smaller than R, followed by two in next highest range. Anal area slightly wider than iBrr areas, anal opening on tegmen not available for study. Plates of lower cup complexly stellate on holotype with seven ridges crossing from R to PBr_1. Plates on figured paratype stellate but with markedly different pattern. Tegmen plates moderately large and covered with pustules.

Occurrence.—Banff formation, Maligne Lake area, Jasper Park, Alberta.

Types.—Holotype GSC No. 9962; paratype GSC 9963.

PERIECHOCRINITIDAE Wachsmuth and Springer
ATHABASCACRINUS n. gen.

Genoype.—*Athabascacrinus colemanensis* n. sp.

The new genus *Athabascacrinus* is erected for a single species whose ancestry can be found only in Devonian megistocrinids. Like *Maligneocrinus* n. gen. and *Sunwaptacrinus* n. gen. it tends to show the early Mississippian nature of the Banff fauna.

Athabascacrinus is closely related to Devonian megistocrinids and may be directly descended from middle Devonian *Megistocrinus depressus* Hall. *Athabascacrinus* has the typical broad, bowl-shaped cup of *Megistocrinus* but differs from most megistocrinids in the grouped, projecting, arm-base areas, depressed interbrachial and interambulacral areas, particularly at the arm levels, heavy, conspicuously large, oral plates with a central, slightly spinose plate, and the laterally directed anal opening situated only slightly above the arm levels. Almost all of these characters are forecast in *M. depressus* from the Middle Devonian rocks of New York. Even the peculiar vermicular type of plate markings found in the New York species are present in *Athabascacrinus*.

Cup similar in shape to *Megistocrinus*, deeply bowl-shaped, with gradually sloping lateral walls, BB and RR laterally directed, interbrachial and anal areas with many plates. BB three, equal. RR five plus X, PBr_1 hexagonal. PBr_2 pentagonal, axillary. SBrr one or two, variable. TBrr mainly lost with arms, two present in two of the rays. Primary iBr large, followed by two plates except between right posterior and right anterior rays where it is followed by three. X slightly larger than RR, followed by three plates in next range. Anal area broadly developed. X opens through a small pyramid surrounded by small plates, laterally directed slightly above the arm level.

Arms unknown, bases markedly projecting, with iBr areas deeply depressed between arm groups. Arms laterally directed.

Tegmen plates each with small sharp, central spine, small over ambulacral areas, larger over oral area. Large, single, central plate, surrounded by seven slightly smaller oral plates; three smaller plates interject themselves between the oral plates on posterior. Interambulacral areas markedly depressed.

Column round, apparently of alternately expanded columnals. Only three columnals preserved on holotype.

Surface delicately marked with curving vermicular ridges, plate corners all markedly depressed, giving a rudimentary stellate appearance.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype GSC No. 9964; paratype No. 9965.

ATHABASCACRINUS COLEMANENSIS n. sp.
Plate 68, figs. 1–3; plate 69, figs. 16–18

Athabascacrinus colemanensis is known from only two specimens on neither of which is the arms preserved.

Cup broadly expanded, bowl-shaped, widest at arm bases, dorsal cup approximately two-thirds of the height of the calyx. BB three, equal, laterally directed, projecting only slightly beyond column, in slight concavity, definitely not forming basal rim. RR five plus X, in lateral contact, RR slightly smaller than X, width 3.9 mm., height 4.1 mm. in holotype. PBrr two, first hexagonal, second pentagonal, first 4 mm. wide, 2.3 mm. high, second slightly smaller. SBrr variable, one, axillary in RP and LP rays, one axillary on RA side and two on LP side of A ray, one axillary on LP side and two on A side of LA ray. TBrr mainly lost with arms, two present in two of the rays. Primary iBr large followed by two plates except between RP and RA rays where it is followed by three. X larger than RR, followed by three in next range, broadly developed up through arm level. X opens from small pyramid, laterally directed, surrounded by minute plates located just above arm level.

Arms unknown, bases markedly projecting, facets directed laterally and slightly upward, apparently four on each of RP and LP rays, two on LA ray and three on A and RA rays. Probably biserial with first bifurcation well above cup.

Tegmen plates larger than is normal for most megistocrinids from which *Athabascacrinus* was derived, depressed in interambulacral areas, larger and raised over the ambulacral areas, conspicuously large over the oral area where a single spinose, central plate is surrounded by seven slightly smaller oral plates. Three smaller plates interject themselves between the oral plates on the posterior side. Each plate marked with a low spine.

Column round, apparently of alternately expanded columnals and typical of *Megistocrinus*. Only three columnals are preserved on the known specimens.

Remarks.—*Athabascacrinus* is most closely

related to *Megistocrinus depressus* from Middle Devonian rocks. It differs in that it has deeply depressed plate corners, larger tegmen plates, large oral plates, and a different position for the anal opening.

Occurrence.—Banff formation, uppr crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. No. 9964; paratype No. 9965.

DESMIDOCRINIDAE Moore and Laudon, 1943
Genus AOROCRINUS Wachsmuth and Springer, 1897

Aorocrinus evolved from Devonian desmidocrinids, and carried on into the Mississippian to become common in Kinderhookian and Osagian rocks. *Aorocrinus* gave rise to the Batocrinidae sometime in the interval between the Devonian and Mississippian since *Batocrinus* occurs first in early Kinderhookian rocks. Batocrinids diversified rapidly in the Osage and disappeared with equal rapidity near the end of the Osage so that only the single genus *Dizygocrinus* survived into the Meramec. Early Kinderhookian batocrinids are identical with *Aorocrinus* except that they have a long anal tube. The presence or absence of such an anal tube is difficult to determine on specimens in which the arms are preserved.

Three species, represented by a total of only four specimens in the Banff fauna, can be referred to the genus *Aorocrinus*. Of the three, only one is sufficiently well exposed in the tegmen area to be absolutely certain that the species belongs with *Aorocrinus* and not *Batocrinus*.

AOROCRINUS BANFFENSIS n. sp.
Plate 67, figs. 18–19; plate 69, fig. 19

This species is represented by a single specimen with the arms and column missing. Cup conical, expanding to arm bases, approximately two-thirds total height of calyx, height of cup 13 mm., width at arm bases 22 mm. BB three, equal, projecting slightly downward, base excavated, basal sutures deeply excavated giving base a trilobed appearance. Basal-radial suture excavated making a basal rim to the cup. RR five, in contact except at posterior, width 5 mm., height 3.5 mm. PBr_1 small, quadrangular, width 3.5 mm., height 2 mm. PBr_2 pentagonal or hexagonal, width 4 mm., height 2 mm., axillary. SBrr two, second axillary. TBrr followed immediately by free arm plates. Primary iBr large, resting on the truncated lateral surface of the RR and rising almost to the level of the top of PBr_2, followed by two small plates. Interbrachial areas depressed beginning at the top of iBr_1 making the cup distinctly lobate at the arm level. Arms grouped, iBrr in contact with tegmen plates. Anal plate large, slightly narrower and distinctly higher than RR. Anal series irregular for desmidocrinids in that X is followed by only two plates instead of three. This is an advanced stage of evolution since elimination of X plates was a trend followed by most crinoids throughout the Paleozoic. The remnant of the third X_2 plate can be seen notching the tops of the other two plates and definitely projecting down below the succeeding cycle. The remaining plates in the X area are small and irregular. The anal area is markedly broader than the iBrr areas. The anal opening is laterally directed from a raised pyramid slightly below the highest part of the tegmen. Tegmen plates are medium in size, nodose in the ambulacral areas, and depressed in the interambulacral areas. A suggestion of a single spine caps the oral area.

Remarks.—The shape of this species of *Aorocrinus* definitely forecasts the shape seen in the genus *Dorycrinus*, a later development in the desmidocrinids. *Aorocrinus banffensis* is undoubtedly an end in its own line of evolution as shown by the presence of only two anals above the X. No other aorocrinid with this advanced anal development is known. *A. banffensis* most closely resembles *A. immaturus* Wachsmuth and Springer from the Hampton formation, LeGrand, Iowa, in general appearance. It can be separated on the basis of the anal area and that *A. banffensis* has a larger, much more rapidly expanding cup than *A. immaturus*.

Occurrence.—Banff formation, lower crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9966.

AOROCRINUS sp.
Plate 67, fig. 20

This species is represented by a single specimen which consists of a complete cup with a considerable portion of the arms preserved. It is referred to *Aorocrinus* because of the resemblance of general cup-shape to the LeGrand species *A. immaturus*, and due to the fact that no anal tube can be seen protruding from the arms. It is possible that it is a primitive batocrinid. The type of plate markings on the dorsal cup are sufficiently different from any known primitive species of either *Aorocrinus* or *Batocrinus* to suggest assignment of a specific name. It is figured here for its stratigraphic value.

A small species, conical, expanding to arm bases, height of cup 7 mm., width at arm bases 12 mm. BB three, equal, not projecting to form a rim. RR five plus X width 2 mm., slightly greater in height. PBr_1 small, quadrangular, PBr_2 pentagonal, axillary, slightly wider than PBr_1. SBrr two, second axillary. TBrr one or two followed by free arm plates. Primary iBr large, reaching from upper surface of RR to top of SBr_1, followed by two small plates, iBr area only slightly depressed, arm groups not markedly projecting. Anal both higher and wider than RR, followed by three plates in next range, the second of which has a strange, supplementary cross piece across the central portion. Remaining anal plates irregular, small.

Arms incomplete, four in at least one of the rays, biserial, stout, uniserial brachials at base of arms few.

Plates marked with very fine, delicate, stellate ridges, sutures deeply impressed. These stellate markings are finer than the markings observed on any other species of *Aorocrinus*.

Remarks.—The cup and crown resemble most closely *A. immaturus* from the Hampton formation at LeGrand, Iowa, but the delicate plate markings separate it immediately from *A. immaturus*. The type of plate markings forecast the relatively heavy stellate markings found on *A. douglassi* from the Lodgepole formation, Montana, and *A. radiatus* from the Hampton formation at LeGrand, Iowa.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC Nos. 9967.

AOROCRINUS IOLA Laudon
Plate 67, figs. 16, 17

Two specimens are referred tentatively to *Aorocrinus iola*, originally described from the Gilmore City formation of Iowa. Both specimens are somewhat distorted. The BB do not appear to make as definite a part of the cup as they do in *A. iola* but this may be due to the flattened preservation. *A. iola* is characterized by four simple arms to the ray in which the biserial character is not developed until a considerable distance above the cup.

Occurrence.—Banff formation, lower crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9968, 9969.

BATOCRINIDAE Wachsmuth and Springer, 1897
SUNWAPTACRINUS n. gen.

Genotype.—*Sunwaptacrinus brazeauensis* n. sp.

The new genus *Sunwaptacrinus* exhibits a stage of evolution between Devonian desmidocrinids and the true Mississippian batocrinids. It sheds considerable light on the probable evolution of the batocrinids.

The fundamental cup-structure is that of a typical batocrinid or desmidocrinid with three equal BB, RR five plus X, PBr_1 quadrangular, iBrr few and large. The arms are primitively grouped as in *Aorocrinus* but are as lobate as in such advanced desmidocrinids as *Dorycrinus*. The anus is at the end of a long, stout, batocrinid tube. The arms, four to each ray, branch for the first time high above the cup in exactly the manner of primitive periechocrinitids such as *Megistocrinus*. The plates are rugose and primitively stellate. The cup is broadly expanding, midway between the bowl-shaped periechocrinitids and the more conical aorocrinids or true batocrinids. Were it not for the primitive megistocrinid structure of the arms, *Sunwaptacrinus* would fall readily within the genus *Uperocrinus*, although it would have a strange appearance and seem not to have close relatives.

The rugose calyx plates, lobate arm

groups, and stout, excellently developed tube indicate that *Sunwaptacrinus* is a specialized end-product of evolution from the Devonian periechocrinitid ancestors of the aorocrinids and not in the direct line of ancestry to any known Mississippian forms. Ancestors of *Sunwaptacrinus* between these Devonian ancestors and the end-product *Sunwaptacrinus* could readily have given rise to desmidocrinids which in turn gave rise to batocrinids. *Sunwaptacrinus*, although temporarily placed in the Batocrinidae, will eventually have to be placed in a new family.

Analysis of genus.—Cup rapidly expanding, flaring abruptly at base of SBrr. BB three, equal; RR five plus X, PBr_1 quadrangular, PBr_2 pentagonal, axillary, SBrr one, axillary, TBrr at least two followed by free arms. Anal followed by three in next range, widely connected to tegmen. Primary iBr large, iBrr few. Cup markedly pentalobate at arm bases, iBrr depressed, anals depressed, ray plates expanded into lobes. All plates rugose.

Tegmen high, followed by long, stout, anal tube, all plates rough and slightly spinose.

Arms biserial immediately beyond cup, branching for the first time high above the cup as in *Megistocrinus* and branching more than once, pinnulate.

Occurrence.—The genus is named for the single species *Sunwaptacrinus brazeauensis*. It is known only from the upper crinoid zone of the Banff formation, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9970; paratypes, GSC Nos. 9971, 9972.

SUNWAPTACRINUS BRAZEAUENSIS n. sp.
Plate 67, figs. 21–23; plate 69, figs. 20, 21

Crown rapidly expanding, maximum width at arm mid-length, recurving at arm tips. Height of crown on holotype 51 mm. to top of anal tube. Height of dorsal cup 15 mm., width at arm bases 34 mm. Height of tegmen and anal tube 36 mm. Arms slightly more than three times the height of the cup.

Cup rapidly expanding to tops of PBrr and flaring abruptly at this point. BB three, low, rugose, projecting to form basal rim, slightly excavated for reception of first columnal. RR large, rugose, width 6.2 mm., height 4.2 mm., in contact except at posterior. PBr_1 quadrangular, rugose, smaller than R, much wider than high. PBr_2 very wide, almost triangular in shape. SBrr one, axillary, papillose. TBrr at least two, followed by free arms, essentially laterally directed. X larger than R, rugose, followed by three large rugose plates in next range, anal area widely expanded, broadly connected to tegmen. Primary iBr large, slightly smaller than R, iBrr few, in contact with tegmen plates, arms definitely grouped, projecting beyond iBrr, giving cup a marked pentalobate appearance.

Tegmen high, grading up into stout anal tube, slightly raised above ambulacral areas, plates heavy, rugose at base, slightly spinose on tube.

Arms heavy, completely biserial immediately above cup, four to each ray, branching twice, first dichotomy high above cup, pinnules long and slender.

The column is not attached but a portion of a large batocrinid column is preserved on the slab near the holotype which undoubtedly belongs with the specimen. It consists of alternately expanded, strong columnals with every fourth columnal expanded more than the second.

Remarks.—One paratype (GSC No. 9972, plate 67, figure 23) is much more definitely stellate and may represent a second species of *Sunwaptacrinus*.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9970; paratypes, GSC Nos. 9971, 9972.

Genus ERETMOCRINUS Lyon and Casseday, 1859
ERETMOCRINUS TENTOR Laudon
Plate 67, fig. 24

This single fragmentary specimen is referred to *Eretmocrinus tentor* and marks one of the earliest occurrences of the genus. *E. tentor* is known from the Gilmore City formation, Kinderhookian, Gilmore City, Iowa.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9973.

ACTINOCRINITIDAE Bassler, 1938
CACTOCRINUS Wachsmuth and Springer, 1897

Five species of *Cactocrinus*, all except one represented by fragmentary remains, have been found in the Banff formation. Two species have been tentatively identified as *Cactocrinus arnoldi* (Wachsmuth and Springer) (Hampton formation, Kinderhookian, LeGrand, Iowa) and *C. imperator* Laudon (Gilmore City, Kinderhookian, Gilmore City, Iowa). Two of the new species have been figured for their stratigraphic value, but due to the incomplete nature of the specimens, we have refrained from presenting names and descriptions until more complete specimens are available. One new species represented by three specimens is described. All three of the new species represent primitive stages in the development of *Cactocrinus* in that the arms are still grouped and interbrachial plates are in contact with tegmen plates. Although Devonian evidence is largely lacking, it seems probable that *Cactocrinus* had its origin in Silurian periechocrinitids. The only fundamental structural changes necessary in the development of *Cactocrinus* from *Periechocrinites* are the loss of one anal plate, the development of an anal tube, and elimination of the grouped arms. The problem of classification of *Actinocrinites* with grouped arms, and *Cactocrinus* with non-grouped arms, is confused. Until the whole problem is clarified these primitive forms are tentatively assigned to *Cactocrinus*.

CACTOCRINUS IMPERATOR Laudon
Plate 68, fig. 4

This species is represented by two more or less fragmentary specimens none of which have the arms or tegmen preserved. The cup-shape, structure, and plate markings are identical with *C. imperator*.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta. Also found in the Gilmore City formation, Gilmore City, Iowa and in the Lodgepole formation, Montana.

Figured specimen.—GSC No. 9974.

Unfigured specimen.—GSC No. 9975.

CACTOCRINUS ARNOLDI (Wachsmuth and Springer)
Plate 68, fig. 5

This species is represented by a single specimen in which neither arms nor tegmen is preserved. The cup is more steeply inclined than that of *C. imperator*, the plates are less stellate and markedly more nodose with deep impressions developed at the plate corners. The specimen compares with some of the more immature specimens of *C. arnoldi* from the LeGrand beds in Iowa.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9976.

CACTOCRINUS sp.
Plate 68, fig. 11

This species is represented by a single specimen in which both dorsal cup and tegmen are present. The stage of evolution represented lies between *Actinocrinites* and *Cactocrinus*, and the species could be referred to either genus. It closely resembles several transitional forms that occur abundantly in the Lake Valley formation (Osagean) in southwestern New Mexico. Until classification problems with regard to these two genera are settled and until further materials are available, it seems inadvisable to describe this species.

The arms are grouped and the interbrachial plates are in contact with tegmen plates. The arms do not project outward from the cup as is common in the more advanced types of *Actinocrinites*. There appear to be twenty arms instead of thirty. The tegmen is high and composed of larger plates. The left anterior ray is irregular in that there is only one PBr.

Occurrence.—Banff formation, lower crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9977.

CACTOCRINUS sp.
Plate 68, fig. 6

This species is represented by a single specimen in which a part of the column, the dorsal cup, and a fragmented portion of the tegmen are preserved. The surface of the specimen has been subjected to weathering so that in part the surface ornamentation

has been altered. Only one side of the cup is available for observation.

The arms are grouped in the primitive position with interbrachial plates in contact with tegmen plates. The tegmen is apparently high and made of relatively small plates. Ambulacral areas appear to be depressed. A primitive ray ridge is present. The surface ornamentation differs from all other known species of *Cactocrinus* in that the plates are delicately stellate and each stellate ridge is broken up into minute granular swellings.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9978.

CACTOCRINUS KUENZII n. sp.
Plate 68, figs. 7–10; plate 69, fig. 22

This species is represented by three specimens, one of which has both arms and anal tube preserved. It is a small, primitive form with the arms grouped, the interbrachial plates in contact with tegmen plates; and it has not developed many of the pinnular spines that characterize all later forms of *Cactocrinus*. It resembles *Actinocrinites* and could be referred to that genus about as readily as to *Cactocrinus* since the stage of evolution is somewhere between the two genera. Since the cup is not pentalobate at the arm levels and the arms are not projected outward, it is referred to *Cactocrinus* until such time as the entire group can be revised.

Height of crown on holotype 24 mm.

BB three, equal, projected outward to form a flange-like rim at the base. RR five, in lateral contact except at posterior, width 2.1 mm., height 1.8 mm. PBr_1 hexagonal, width 1.6 mm., height 1.2 mm. PBr_2 hexagonal or heptagonal, axillary, width 2.2 mm., height 1.1 mm. SBr_1 heptagonal, axillary, 1.8 mm., height 1.2 mm. TBrr one, supporting free arms, a single arm on the outside of the ray and a double arm on the inside of the ray, making six to each ray. TBrr rounded, projecting as a prominent ray ridge and appearing almost as free arm brachials in holotype. Interbrachials well-defined, iBr_1 slightly smaller than PBr_1, followed by 2, 2, 2, 2 and tegmen plates. Anal area broadly defined, wider than iBrr areas. X slightly smaller than RR, hexagonal, followed by two plates in the next range, followed by 4, 4, 3. Plates simply stellate, with a very strong, median ray ridge. Tegmen of unusually small, relatively smooth plates. Ambulacral areas raised, interambulacral areas depressed and of small plates. Tube long, slender, slightly spinose, apparently rising to full height of arms.

Arms six to each ray, first brachial long, second and third short and cuneiform, remaining brachials biserial. Each brachial has a tendency for a node that projects both laterally and outward from each brachial making the arm appear to have a groove-like depression along each side. Pinnules stout, for the most part without the upward-directed spines that characterize all later forms of *Cactocrinus*. Spinose pinnulars identical to those found in later species of *Cactocrinus* occur indiscriminately near the base of some of the arms of this species. The presence of these apparently forecasts their full development in more advanced, later species.

The column has not been observed.

Remarks.—The most primitive forms now referred to *Cactocrinus* have 20 arms. All species having the arms grouped and the iBrr connected with tegmen plates are thought to be primitive. Extensive revision of the genus is indicated. *C. kuenzii* is one of the most primitive known species of the forms that have six arms to each ray. *C. kuenzii* is closely related to several undescribed species in the Lake Valley formation (Osagean) of New Mexico. This stock eventually gave rise to the 30-armed *C. multibrachiatus* Hall type found so abundantly in the Burlington limestone.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9979; paratypes, GSC Nos. 9980, 9981.

PLATYCRINITIDAE Bassler, 1938
Genus PLATYCRINITES Miller, 1821

Five species of *Platycrinites* are recognized in the Banff fauna. One closely related and ancestral to *P. truncatulus* Hall and another closely related and ancestral to *P. incomptus* White are described as new.

One species characterized by zigzag, cuneiform arms is not described because we have several hundred excellent specimens of this species from the Lodgepole formation of Montana and it will be described later. Two species are fragmentary and incomplete. One, a smooth form is related to *P. symmetricus* Wachsmuth and Springer, and the other, a delicately marked form may be related to the *P. nodo-striatus* Wachsmuth and Springer group.

PLATYCRINITES SUNWAPTAENSIS n. sp.
Plate 68, figs. 12–14; plate 69, figs. 23, 24

Cup relatively shallow, bowl-shaped, greatest width at arm bases. BB three, unequal, laterally directed and forming only a small portion of the lateral cup wall. RR five, in lateral contact, expanding slowly to greatest width at top, width 4.1 mm., height 2.7 mm. on holotype. Arm facet excavated from central portion of R, occupying approximately one-third of the width of the plate. Plates without ornamentation.

Arms slender, delicate, six to each ray, reaching 18 mm. in length on holotype. PBrr one, axillary. SBrr two, long, averaging 2 mm. in length. TBrr two on inside branch, also conspicuously long. Outside arm remains unbranched. One arm on inside of ray on holotype branches a fourth time making seven arms to that ray. Arm brachials long, primitively cuneiform, with steeply slanted sutures. Pinnules coarse, ramule-like, rising from projection on each brachial.

Tegmen of relatively large plates, ambulacral plates in primitive, offset position, oral plates very large surrounding a large central plate, interambulacrals few normally 1, 2, 1. Anus eccentric, surrounded by a ring of nodose plates.

Column elliptical, of alternately expanded columnals, twisted.

Remarks.—*P. sunwaptaensis* is one of the most primitive Mississippian platycrinitids we have studied to date. It can be immediately differentiated from other Mississippian species by its primitive, cuneiform arms. The low cup and flattened base resemble *P. truncatulus* and *P. americanus* from the Lower Burlington limestone. The biserial arms of *P. symmetricus* from the Hampton beds at LeGrand, Iowa were probably derived from a form such as *P. sunwaptaensis*. The LeGrand species has long been considered the base stock from which such forms as *P. aequalis* Hall from the Burlington limestone and *P. sarae* Hall from the St. Louis limestone were derived.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9982; paratypes, GSC Nos. 9983, 9984.

PLATYCRINITES DECADACTYLUS n. sp.
Plate 68, figs 17–18; plate 69, fig. 25

Platycrinitids with heterotomously branching arms in which the main arm remains uniserial and the branches become biserial range throughout the Kinderhookian and Osagean rocks. *P. decadactylus* marks the oldest occurrence of platycrinitids with this type of arm branching known to us.

This is a smooth-plated form, with a high cup and a relatively open type of arm structure. Both specimens from the Banff formation are incomplete and flattened.

BB three, unequal, making a conspicuous part of the cup, height 6 mm. in holotype. RR five, in lateral contact, maximum width 10 mm., height 11 mm. in holotype. PBrr one, low, occupying approximately one-third of excavated upper surface of R. SBrr two. TBrr two, uniserial on inside of ray, outside of ray unbranched, biserial immediately above contact with SBr. 4Brr three, uniserial on outside of ray, inside arm unbranched and biserial immediately above contact with TBr. 5Brr three. 6Brr many, arms unbranched, both biserial immediately above contact with 5Br. Pinnules slender.

Tegmen and column unknown.

Remarks.—*P. decadactylus* is closely related to *P. halli* Shumard from the upper Burlington limestone which has eight arms to each ray instead of ten. *P. decadactylus* is also related to *P. pratteni* Worthen which has 12 arms to the ray and *P. incomptus* White which has as many as 22 arms to the ray. The manner of branching of the arms in all three of these species is identical and they probably represent an evolutionary series. *P. sculptus* from the lower Burlington limestone also exhibits this type of arm structure as does *P. hemisphericus* Meek and Worthen from the Keokuk beds of Indiana.

Both of these species have developed decorative markings on the cup plates.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Types.—Holotype, GSC No. 9985; paratype, GSC No. 9986.

PLATYCRINITES sp.
Plate 68, fig. 19

A smooth-plated form with a higher cup than *P. sunwaptaensis* probably related if not identical to *P. symmetricus* from the Hampton formation at LeGrand, Iowa. It is figured here for its stratigraphic value.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9987.

PLATYCRINITES sp.
Plate 68, fig. 15

A small species with a low cup and delicately sculptured plates. Plate markings of the type developed on this species are not known to us on any other species. The arms are in the primitive, uniserial condition. A species name is not assigned because the specimen is incomplete. It is figured for stratigraphic value.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9988.

PLATYCRINITES sp.
Plate 68, figs. 16, 20

This small species of *Platycrinites* was first assumed to represent an immature individual. We have now accumulated over 100 specimens of this species from the Lodgepole formation of Montana representing all stages of development. We are postponing assignment of a specific name to make use of the excellent Lodgepole material. It is a small, low, smooth-plated form with distinctive, long, markedly cuneiform arm brachials.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimens.—GSC Nos. 9989, 9990.

DICHOCRINIDAE S. A. Miller, 1889
Genus DICHOCRINUS Munster, 1837

The genus *Dichocrinus* is represented by five species in the Banff fauna. Not a single species is complete enough to warrant assignment of a specific name with certainty. At least one new species is present and four may eventually be found to represent new forms.

DICHOCRINUS BOZEMANENSIS (Miller and Gurley)
Plate 68, fig. 28

This species from the Lodgepole formation of Montana was described as *Platycrinites* by Miller and Gurley. We now have several excellent specimens in our collections from the Banff area and it seems clear that the species should be referred to *Dichocrinus*. Excellently preserved specimens of this species are now known from the Gilmore City formation of Iowa.

A single specimen, without arms, in the Banff fauna is referred to this species. The striated cup markings so well-developed in the Gilmore City and Lodgepole representatives of this species are not well-developed in the Banff specimen.

D. bozemanensis differs from all other species, except some later specialized Keokuk forms, in that the cup expands continuously up to the top of the cup. Normal dichocrinids tend to have high straight-sided cups.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9991.

DICHOCRINUS sp.
Plate 68, figs. 21–24

This species is represented by one excellent specimen that shows the cup and tegmen and another fragmentary specimen with a small part of the column attached. We have hesitated to assign a species name without knowledge of the arms.

It is a smooth-plated form, with a high, narrow cup. It is probably identical with *D. multiplex* Laudon from the Gilmore City formation of Iowa with which it compares closely. The cup is also similar to that of *D. crassitestus* White from the upper Burlington limestone. Without knowledge of the arms, a specific assignment cannot be made.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC Nos. 9992, 9993.

DICHOCRINUS sp.
Plate 68, figs. 25, 26

This small slender species is represented by a single, partially incomplete specimen. It has a striated cup of the type seen in *D. cinctus* Miller and Gurley from the Hampton formation, LeGrand, Iowa. The cup of the Banff species is higher and more slender than the LeGrand form. *D. oblongus* Wachsmuth and Springer from the Warsaw formation of the upper Mississippi Valley area is probably related to this species. The striations on the Warsaw species are lighter and the cup is not as narrow.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9994.

DICHOCRINUS sp.
Plate 68, fig. 27

This species is represented by a single specimen, without arms, on which a part of the column is attached. The cup is low and the plates are striated much as they are in *D. pisum* Meek and Worthen from the Lower Burlington limestone. The striations are not unlike the type developed in *D. cinctus* from the Hampton formation at LeGrand, Iowa. The cup is shorter than that of the LeGrand form.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Alberta.

Figured specimen.—GSC No. 9995.

DICHOCRINUS sp.
Plate 68, figs. 29, 30

This species of *Dichocrinus* is also represented by a single fragmentary specimen. It is a widely expanding form, somewhat similar to *D. bozemanensis* Miller and Gurley but much more delicately marked. The markings on the cup of this form are more delicate than in any form known to us. It undoubtedly represents a new species.

Occurrence.—Banff formation, upper crinoid zone, Sunwapta Pass area, Albert.

Figured specimen.—GSC No. 9996.

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ORBULINA UNIVERSA D'ORBIGNY IN CENTRAL SUMATRA

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ABSTRACT—The purpose of this paper has been to record the vertical range of *Orbulina universa* d'Orbigny in the Tertiary of Central Sumatra and to re-emphasize the importance of the lower limit of this species as a possible middle Tertiary time indicator in proper marine Tertiary sections within present-day low latitudes of the world.

INTRODUCTION

THE possibility of *Orbulina universa* d'Orbigny, a pelagic foraminifer, as an inter-regional middle Tertiary time indicator was recognized by the writer while involved in biostratigraphic studies of Central Sumatra and contiguous areas in 1936–1942. Data upon which this concept was based were obtained from numerous surface sections along the east front of the Barissan Mountains of west-central Sumatra and from wells drilled in the East Coastal Plains area of the island.

The writer (1948) suggested that points of lowest stratigraphic occurrence of *Orbulina universa* d'Orbigny, and its related form, *Candorbulina universa* Jedlitscka, in a continuously deposited, open sea, deep-water globigerine biofacies, fall on or in close proximity to a time horizon within middle Tertiary sections of present tropical and subtropical areas of the world. Qualified "points of lowest stratigraphic occurrence" in stratigraphic sections are controlled by the following factors: (1) proper biotic facies, (2) continuous sedimentation during the time interval in which *Orbulina* was first biologically introduced into the geologic column, and (3) rapid geological dispersal of the genus at time of biologic initiation.

The Kassikan section near Aliantan, Sultanate of Siak, Central Sumatra (fig. 1) sampled by the late G. L. Hofsteenge of the Nederlandsche Pacific Petroleum Maatschappij, forms the basis of this paper. In this section the base of *Orbulina* was established within three feet stratigraphically. Lithostratigraphic and biostratigraphic details of this section are presented for the following purposes: (1) to establish the stratigraphic base of *Orbulina* in Central Sumatra, (2) to place on record a section which is believed to fulfill requirements for placing a qualified point on the suggested *Orbulina* surface, (3) to give a summary of the common pelagic and benthonic Foraminifera of Central Sumatra, (4) to indicate the major micro-biostratigraphic subdivisions of the Kassikan section, and (5) to summarize the stratigraphy of Tertiary strata outcropping along the east front of the Barissan Mountains of west-central Sumatra.

The more pertinent species appearing in the Kassikan sequence are illustrated and their biostratigraphic ranges and relative abundances shown (fig. 3). Brief comment is devoted to each species.

LITHOSTRATIGRAPHIC SUMMARY

The Kassikan section involves four cartographic units from oldest to youngest as follows: pre-Telisa Tertiary sandstones, Telisa, lower Palembang and middle Palembang. The combined thickness of these deposits exceeds 4000 feet.

PRE-TERTIARY

The pre-Tertiary consists of highly dipping, brownish-gray, jointed quartzites. A series of sandstones of probable early Tertiary age unconformably overlies these strata.

TERTIARY

Pre-Telisa sandstone.—The age of this unit is doubtful owing to its continental aspects. Most workers agree to an early Tertiary assignment. It consists of massive to poorly-bedded, friable, medium-to coarse-grained, white to buff sandstones containing thin interbeds of silty shales, mudstones and conglomerates. Secondary faceting is common on quartz grains. Tourmaline,

zircon, and biotite comprise the major elements of the heavy mineral fractions.

The sandstone is widely distributed along the east front of the Barissan Mountains. In the Kassikan section the thickness of the unit exceeds 2000 feet. At other localities thicknesses have been recorded up to 5000 feet.

The sandstones rest with angular unconformity on the pre-Tertiary and are, for the most part, seemingly conformable with the overlying Telisa.

Telisa formation.—The Telisa of the Kassikan section, as well as elsewhere along the Barissan Mountain front, consists of thin-bedded, gray-brown to greenish-brown, highly foraminiferal shale and marlstone. Silty, glauconitic shales and thin, discontinuous calcareous layers occur sporadically throughout. The deposits represent the *Globigerinoides* facies of the formation (fig. 2). Eastward these sediments grade into alternating shales, siltstones and sandstones which micropaleontologically are designated as the *Textularia* facies (LeRoy, 1944).

The Telisa is widespread over the greater part of Central Sumatra. Its thickness varies from 630 to 2870 feet. The latter figure represents that of the Kassikan section.

The Telisa of the Kassikan section is conformable with the underlying early Tertiary sandstones and with the overlying lower Palembang. In the East Coastal Plains area a pronounced unconformity marks the latter boundary.

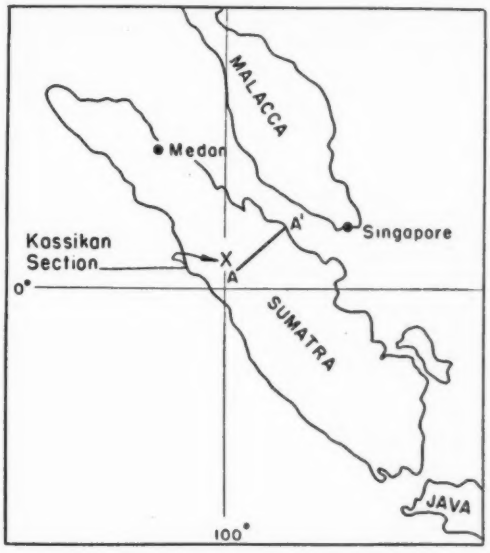

FIG. *1*—Index map of Sumatra showing position of Kassikan section and position of schematic cross-section given in fig. *2*.

The *Globigerinoides* facies of the Telisa is considered as having been deposited under rather deep neritic, open-sea conditions, whereas, the *Textularia* facies is believed to represent a shallow-water, near shore environment. Pelagic Foraminifera occur profusely in both facies.

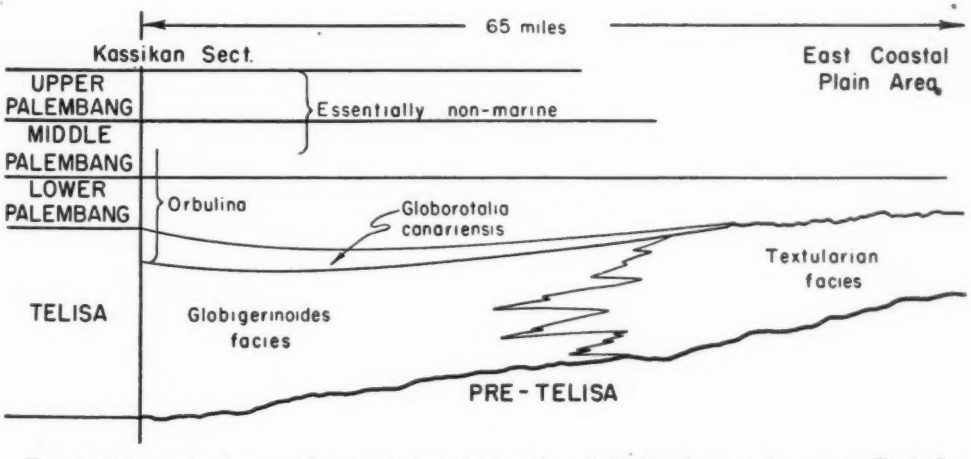

FIG. *2*—Schematic diagram showing facies relationships of the Tertiary section across Central Sumatra. Location given in fig. *1*.

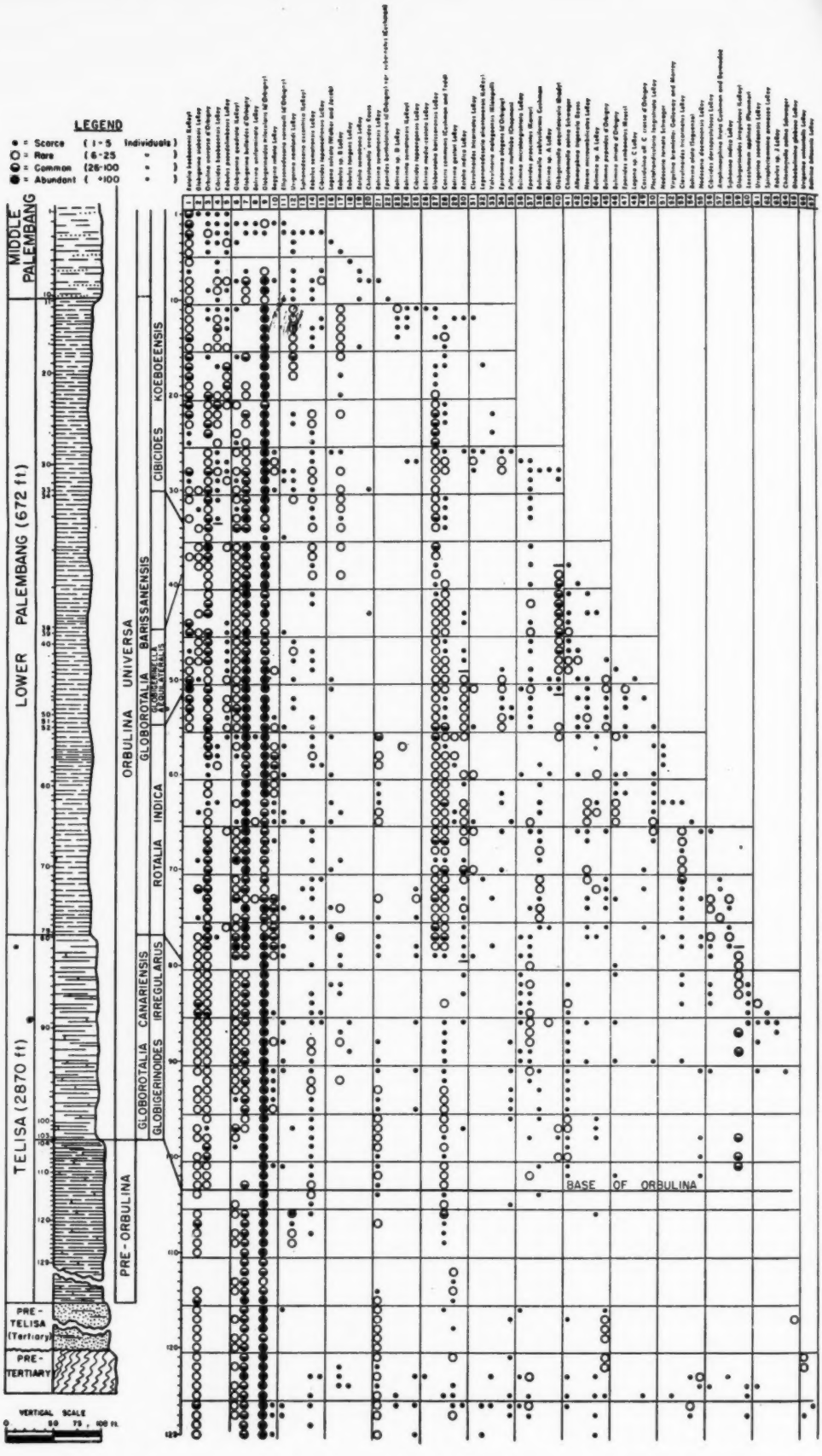

FIG. 3.—Foraminiferal distribution chart of the Kassikan section of Central Sumatra.

Lower Palembang formation.—The lower Palembang deposits of the Kassikan section consist of dark silty, greenish-gray foraminiferal shales containing frequent thin interbeds of glauconitic siltstone and fine-grained, argillaceous sandstones. The greenish cast distinguishes these sediments from those of the Telisa which exhibits more brownish hues.

The formation outcrops widely along the east front of the Barissan Mountains. It is also widely distributed in the subsurface of the East Coastal Plains area. Thicknesses of the unit range from 181 to 1666 feet. Six hundred and seventy-two feet were measured in the Kassikan section.

Along the east front of the Barissans, the Telisa-lower Palembang boundary is transitional. The lower boundary of the lower Palembang lies about 200 feet stratigraphically above the base of *Orbulina*. This contact in the East Coastal Plains area is defined by an unconformity. The lower Palembang-middle Palembang contact is gradational throughout Central Sumatra though unconformable relationships may exist locally.

Middle Palembang formation.—Only the lower portion of the middle Palembang is exposed in the Kassikan section. It consists primarily of fine- to medium-grained, argillaceous to silty sandstones, silty, yellowish-green shales and mudstones containing minor amounts of glauconite.

The formation outcrops extensively along the Barissan Mountain front and in the East Coastal Plains area. Its thickness may range up to more than 1500 feet. The sediments are mixed marine and non-marine with the latter type most prevalent. These deposits represent a closing cycle of basinal siltation.

The formation boundaries are gradational with the underlying lower Palembang and overlying upper Palembang.

Post middle Palembang deposits.—Sediments overlying the middle Palembang in the East Coastal Plains area vary lithologically and in part have been included in the upper Palembang formation by some workers. Non-marine claystones, siltstones, fine-grained, argillaceous sandstones and occasional lignite beds constitute the sequence. Fresh-water diatoms, coprolites and few arenaceous Foraminifera comprise the fossil assemblage.

BIOSTRATIGRAPHIC SUMMARY

The lower limit of *Orbulina universa* d'Orbigny reflects one of the most pronounced Tertiary microfaunal breaks in Central Sumatra and is accurately defined in the Kassikan section. This species occurs in the upper 214 feet of the Telisa, throughout the lower Palembang and sparingly in the lower part of the middle Palembang. The *Orbulina*-bearing portion of the Kassikan section may be subdivided into a number of specific faunas and faunules as shown in figure 3.

Globorotalia canariensis *fauna.*—This fauna is typified by *Globorotalia canariensis* and *Globigerinoides irregularus*. It characterizes the lowermost 214 feet of the *Orbulina* interval and falls within the uppermost part of the Telisa. The general diversity of this fauna is more restricted than the overlying assemblages. The fauna fails to appear in the East Coastal Plains area because of unconformity.

Globorotalia barissanensis *fauna.*—This fauna constitutes the upper two-thirds of the *Orbulina* interval and occurs throughout the lower Palembang formation. The fauna contains three distinct faunules from oldest to youngest as follows: *Rotalia indica*, *Globigerinella aequilateralis* and *Cibicides koeboeensis*.

1. *Rotalia indica* faunule.—This faunule has a thickness of 220 feet and is well developed in the lower part of the lower Palembang formation. The upper limit is defined by entrance of *Epistomina elegans*, a species seemingly restricted to the lower Palembang of Central Sumatra. *Rotalia koeboeensis* initiates its vertical range near the top of this faunule.
2. *Globigerinella aequilateralis* faunule.—This faunule immediately overlies the *Rotalia indica* faunule and is distributed through a thickness of 100 feet.
3. *Cibicides koeboeensis* faunule.—The upper 200 feet of the lower Palembang is characterized by this faunule although the index species ranges stratigraphically upward into the middle Palembang.

Pre-Orbulina *faunas.*—Microfaunal assemblages within the pre-*Orbulina* portion of the Telisa consist primarily of globigerine forms and constitute the *Globigerinoides* facies of the formation. Further eastward this facies fauna grades into shallower-water faunas which have been paleontologically assigned to the *Textularia* facies.

Because of the homogeneity of the pre-*Orbulina* Telisa microfaunas, biostratigraphic subdivisions are difficult; however, more detailed analysis of the globigerine forms may permit subdivision.

GENERAL COMMENTS ON *ORBULINA UNIVERA* D'ORBIGNY

During the past two years the writer has requested discussion from micropaleontologists the world over concerning the distribution of *Orbulina* in various Tertiary sections (fig. 4). I wish to extend my gratitude to these individuals for the following comments which may stimulate other workers interested in pelagic Foraminifera as possible time indicators.

According to ten Dam[1], the Oligocene of Algeria seems to be characterized by *Globigerina venezuelana* and by the complete absence of *Orbulina*. He states, "It seems that the *Orbulina* surface in Algeria lies at the base of the Miocene." Stainforth (1949) recognized *Candorbulina* only in the Miocene of Egypt.

Tromp[2] comments that in the Tertiary section of Southern Turkey, *Orbulina* disappears in marl sections below the basal Miocene. He says, "The *Orbulina* surface is also in my opinion a very good time marker which could be used for world-wide correlation as long as the Tertiary is developed in a favorable Globigerinidae facies."

In the Agua Salada Group of Eastern Falcon, Venezuela, *Orbulina* makes its first appearance in the "*Uvigerinella*" *sparsicostata* zone ("probably middle Oligocene") but is extremely rare. According to Renz (1948) it becomes rare but persistent in the *Siphogenerina transversa* zone (upper Oligocene) and common to abundant in the overlying *Globorotalia foshi* zone (upper Oligocene). Renz[3] further states, "It appears to me that in the Caribbean region the species *Orbulina universa* appears questionably in the Middle Oligocene, is scarce in the lower part of the Upper Oligocene and becomes really abundant in the top of the Upper Oligocene and Miocene."

In a letter dated July 14, 1947, Bermudez[4] comments, "With respect to *Orbulina universa* and *Orbulina bilobata*, I can inform you that these species apparently did not exist in formations older than the Middle Oligocene in the sections of Cuba and Hispaniola."

Cushman and Stainforth (1945) first record *Orbulina* in the *Globorotalia foshi* zone (upper Oligocene) of Trinidad. This point was verified by the writer in 1947.

Stainforth (1947) states that in Ecuador, "The species (*Orbulina*) ranges from late Oligocene through the Miocene and in range is the same in Colombia according to private communication from C. D. Redmond."

As regards the stratigraphical distribution of *Orbulina* in the Pacific Coast section, Laiming[5] remarks, "The Pacific Coast record indicates abundance of *Orbulina* in the Upper Tertiary and Lower Pleistocene, rare occurrence in the Middle Tertiary and questionable or none in the Lower Tertiary."

Bainton[6] failed to recognize *Orbulina* in any Cretaceous, Eocene or Oligocene material from the San Joaquin Valley of California but states that very rare and doubtful specimens occur in the middle Miocene on the east side of the valley.

Holman and Ruth[7] state, "We conclude

[1] ten Dam, A., Societe Nationale de Recherche, Relizane, Algeria, written communication, September, 1948.

[2] Tromp, S. W., Fouad University, Cairo, written communication, January, 1949.

[3] Renz, H. H., Mene Grande Oil Co., Caracas, Venezuela, written communication, December, 1947.

[4] Bermudez, J. P., Creole Petr. Corp., Caracas, Venezuela.

[5] Laiming, Boris, The Texas Company, Los Angeles, California, written communication, July, 1947.

[6] Bainton, J. D., Standard Oil Company of California, Taft, California, written communication (April, 1949) to W. Barbat of the Standard Oil Company of California forwarded to the writer.

[7] Holman, W. H., and Ruth, J. W., Standard Oil Company of California, Los Angeles, written communication (March, 1949) to W. Barbat and forwarded to writer.

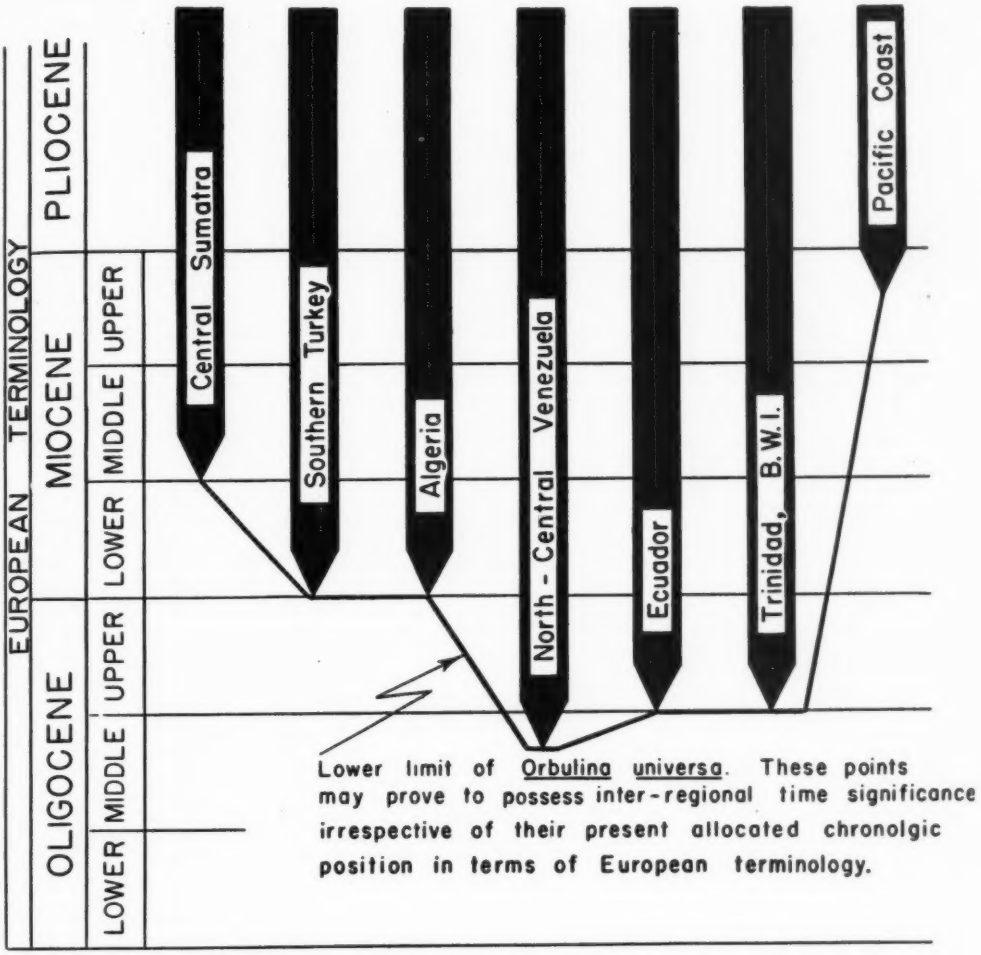

FIG. 4—Showing lowest stratigraphic positions of *Orbulina universa* d'Orbigny in Sumatra as compared with other world-wide localities.

that the datum of first appearance of *Orbulina* is within the middle of the Mohian stage and is clearly within the Miocene as established by the larger invertebrates in the Southern Californian coastal region."

Bandy[8] comments, "I have not observed *Orbulina universa* in the Oligocene or earlier strata on the Gulf Coast."

From the foregoing it appears that *Orbulina* makes its entrance into the Tertiary section of the Caribbean region about late "middle Oligocene" or early "upper Oligocene." The species in the Middle East appears to go no lower than the "lower Miocene" as is also the case in the Gulf Coast region. In the Netherlands East Indian province the species appears to have its lower limit within the "Miocene." The question now arises as to the equivalency of the "middle Oligocene," "upper Oligocene," and "lower Miocene," used by the various workers. The development of the *Orbulina* surface may assist in more accurately adjusting the contemporaneity of these age assignments.

The writer is of the opinion that the base of *Orbulina*, provided proper facies are involved, in the low latitudes of Pacific realm

[8] Bandy, O. L., University of Southern California, Los Angeles, California, written communition, April, 1949.

would provide a reliable correlative time horizon within the Tertiary. The form is introduced into the "upper Oligocene" of Ecuador and Colombia, therefore, suggesting an equivalent assignment of the upper part of the Telisa and possibly the lower Palembang of Sumatra.

COMMENTS ON FORAMINIFERA* OF THE KASSIKAN SECTION

Rotalia koeboeensis (LeRoy) (1).—Occurs in appreciable numbers and rather persistently in upper three-fourths of lower Palembang; limited in middle Palembang; found in restricted numbers within Telisa at various locales in East Coastal Plains area.

Globigerina siakensis LeRoy (2).—Occurs sporadically throughout lower Palembang reaching best development in middle part; abundant and persistent throughout Telisa, initiating its best development at top of *Globorotalia canariensis* faunule.

Orbulina universa d'Orbigny (3).—Occurs abundantly and persistently within lower Palembang; rare in base of middle Palembang and abundant in upper 214 feet of Telisa. The lowermost stratigraphic occurrence of this species has been accurately placed in the Kassikan section. In the upper part of the Telisa it is associated with *Globorotalia canariensis*.

Cibicides koeboeensis LeRoy (4).—Occurs commonly in upper fourth of lower Palembang; scarce in basal part of middle Palembang. No record of the species has been made from the Telisa other than in its *Textularia* facies where it is only rarely encountered.

Robulus pseudolimbosus LeRoy (5).—Occurs throughout lower Palembang of the Kassikan section; also observed within Telisa.

Globigerina quadrata (LeRoy) (6).—Abundant specimens in both lower Palembang and Telisa. The species has no stratigraphic significance. Numerically the species decreases in the uppermost lower Palembang; few specimens noted in the middle Palembang.

Globigerina bulloides d'Orbigny (7).—One of the most common pelagic forms of the lower Palembang and Telisa faunas; number of individuals become less as the middle Palembang is approached.

Bolivina uniforminata LeRoy (8).—Few species observed in section above the Telisa. In some lower Palembang faunas the species occurs in considerable abundance.

Globigerinoides trilocularis (d'Orbigny) (9).—Abundant in all faunas of the Kassikan section; becomes less conspicuous in middle Palembang portion of the section.

* Numbers following species correspond to the number on the distribution chart (fig. 3). Refer to LeRoy (1944) for figures of species.

Baggina inflata LeRoy (10).—Attains best development in lower part of lower Palembang; few scattered specimens observed in Telisa.

Ellipsonodosaria verneuili (d'Orbigny) (11).—Sporadically scattered throughout the Kassikan section.

Uvigerina nomlandi LeRoy (12).—Scattered throughout lower Palembang and lower part of middle Palembang; most persistent in uppermost lower Palembang; few specimens noted just below base of *Orbulina*.

Siphonodosaria excentrica (LeRoy) (13).—Few scattered specimens noted within lower and middle Palembang.

Robulus sumatrensis LeRoy (14).—Rather persistent in moderate numbers in lower Palembang; best developed in upper part; rare to scarce within Telisa and middle Palembang.

Cibicides tapanoeliensis LeRoy (15).—Sporadic and in limited numbers in lower Palembang; several specimens observed in middle Palembang and Telisa.

Lagena sulcata (Walker and Jacob) (16).—Rare and sporadically distributed in lower part of lower Palembang; several specimens noted in middle Palembang and Telisa.

Robulus sp. B LeRoy (17).—Sporadic throughout Kassikan section but best developed in upper fourth of lower Palembang.

Robulus tangens LeRoy (18).—Only several specimens observed in the Kassikan section.

Rotalia sumatrana LeRoy (19).—One specimen noted in uppermost lower Palembang and several from middle Palembang. The species appears to be best developed in Central Sumatra in section above the lower Palembang.

Chilostomella ovoidea Reuss (20).—This variety noted in only several samples from upper part of lower Palembang and from one in middle Palembang.

Bolivina sumatrensis LeRoy (21).—This species is persistent in appreciable numbers in lower fourth of lower Palembang; frequent in Telisa. Its upper limit is marked approximately by the base of *Epistomina elegans*. The species is one of the most widespread forms in the Central Sumatran marine Tertiary.

Eponides berthelotiana (d'Orbigny) var. *subornatus* (Cushman) (22).—Rare in basal part of middle Palembang; not observed elsewhere in Kassikan section.

Bolivina sp. D LeRoy (23).—Rare in extreme upper part of lower Palembang.

Bolivinita sumatrensis (LeRoy) (24).—Seemingly confined to uppermost lower Palembang; stratigraphic position appears to conform with that of other Central Sumatran sections.

Cibicides tapoengensis LeRoy (25).—Scattered in limited numbers in lower Palembang and Telisa.

Bolivina media-costata LeRoy (26).—One specimen noted just below middle Palembang-lower Palembang contact.

Globorotalia barissanensis LeRoy (27).—Common throughout lower Palembang; an excellent marker; basal limit conforms with top of Telisa. This species shows considerable affinity to *G. fohsi* Cushman and Ellisor of the West Indian region.

Cancris communis (Cushman and Todd) (28).—Present throughout Telisa and lower Palembang but best developed in lower part of latter unit; rather persistent in upper part of Telisa and scattered below. This species is a favorable indicator for the lower part of the *Globorotalia barissanensis* fauna.

Bolivina gesteri LeRoy (29).—Sporadically distributed in limited numbers.

Rotalia indica LeRoy (30).—Most prominantly developed in lower part of *Globorotalia barissanensis* fauna; rare in upper part of lower Palembang and uppermost part of Telisa (*Globorotalia canariensis* fauna).

Clavulinoides tricarinatus LeRoy (31).—Occurs in limited numbers in lower Palembang; recorded from Telisa at other localities.

Lagenonodosaria aliantanensis (LeRoy) (32).—Rare and sporadic in lower Palembang and Telisa.

Valvulineria malagaensis (Kleinpell) (33).—Scattered specimens in lower Palembang and Telisa.

Epistomina elegans (d'Orbigny) (34).—Confined entirely to lower Palembang; best development attained in upper part of *Rotalia indica* faunule; an index form for the lower Palembang.

Pullenia multiloba (Chapman) (35).—Sporadically distributed in limited numbers in lower Palembang and Telisa.

Bulimina microlongistriata LeRoy (36).—Occurs in limited numbers and sporadically distributed in both lower Palembang and Telisa strata.

Eponides praecinctus (Karrer) (37).—Rather frequent in lower Palembang; scarce in Telisa of Kassikan section though locally common in Telisa of other localities.

Buliminella subfusiformis Cushman (38).—Irregularly distributed in lower Palembang and uppermost part of Telisa; frequently noted in middle Palembang of other localities; not observed in Telisa of Kassikan section.

Bolivina sp. A LeRoy.—Very rare in lower Palembang.

Globigerinella aequilateralis (Brady) (40).—Present in lower Palembang and uppermost Telisa; best development attained immediately above the *Rotalia indica* faunule. This form may, upon further investigation, prove to have excellent correlative value owing to its pelagic nature.

Chilostomella oolina Schwager (41).—This form appears throughout the lower Palembang and Telisa. It is most persistent above the base of *Orbulina*.

Allomorphina trigonula Reuss (42).—Confined entirely to lower half of lower Palembang; restricted to and considered a marker for the formation. It has not been observed within the Telisa or below *Orbulina universa*.

Nonion microumbilicatus LeRoy (43).—Sporadic in lower part of lower Palembang and uppermost Telisa; best developed in *Rotalia indica* faunule.

Bulimina sp. A LeRoy (44).—Scattered specimens throughout lower part of lower Palembang and in Telisa.

Bulimina pupoides d'Orbigny (45).—Limited numbers in lower part of lower Palembang and throughout Telisa; vertical range greater than shown in the Kassikan section.

Bulimina striata d'Orbigny (46).—Scattered in lower part of lower Palembang and in upper part of Telisa; has long stratigraphic range in Central Sumatra.

Eponides umbonatus (Reuss) (47).—Confined to lower part of lower Palembang; most frequent in upper part of *Rotalia indica* faunule; not observed in Telisa.

Lagena sp. C LeRoy (48).—One specimen noted in lower Palembang.

Cassidulina aff. *C. crassa* d'Orbigny (49).—Rare in lower part of lower Palembang; one specimen observed in uppermost Telisa.

Plectofrondicularia longistriata LeRoy (50).—Most persistent though limited in numbers in upper part of *Rotalia indica* faunule; rare in Telisa of other localities.

Nodosaria tornata Schwager (51).—Few specimens in basal part of lower Palembang.

Virgulina bramlettei Galloway and Morrey(52).—One specimen noted in lower part of lower Palembang and one in upper part of Telisa; more commonly encountered in Telisa than in overlying formations.

Clavulinoides tricarinatus LeRoy (53).—Best developed in lower part of *Rotalia indica* faunule; few specimens in uppermost Telisa.

Bolivina alata (Seguenza) (54).—Rare in both lower Palembang and Telisa.

Nodosaria doemaiensis LeRoy (55).—Scarce in basal part of lower Palembang and in Telisa; generally more frequent in latter formation at other localities along Barissan Mountain front.

Cibicides dorsopustulosus LeRoy (56).—Rare in extreme base of lower Palembang and uppermost Telisa. At other localities this species has a higher stratigraphic range than is shown in the Kassikan section.

Amphimorphina lirata Cushman and Bermudez (57).—Observed only in lowermost part of lower Palembang; species seemingly confined to this formation and rarely encountered.

Siphonina indica LeRoy (58).—Occurs at extreme base of lower Palembang and at lower limit of *Rotalia indica* faunule. At other localities it has been noted in the Telisa and middle Palembang in limited numbers.

Globigerinoides irregularis (LeRoy) (59).—Seemingly confined to the uppermost part of Telisa (lowermost part of *Orbulina* interval); considered a reliable index form within Telisa of Barissan Mountain front.

Loxostomum applinae (Plummer) (60).—Scattered throughout Telisa; species not recorded in post-Telisa faunas; generally occurs in limited numbers.

Uvigerina soendaensis LeRoy (61).—Confined to Telisa in Kassikan section though has been recorded occasionally from lower Palembang.

Spiroplectammina arenacea LeRoy (62).—Several specimens noted in uppermost Telisa of Kassikan section; has been recorded in limited numbers in lower Palembang of other localities.

Robulus sp. J LeRoy (63).—Extremely rare in upper part of Telisa, but not entirely confined to this formation elsewhere.

Chilostomella oolina Schwager (64).—Rare in upper part of Telisa though noted elsewhere in lower Palembang.

Globobulimina globosa LeRoy (65).—Few specimens noted in pre-*Orbulina* Telisa of Kassikan section.

Uvigerina uniserialis LeRoy (66).—Rare in pre-*Orbulina* Telisa of Kassikan section; few specimens noted from middle Palembang at other localities.

Bolivina bilaensis LeRoy (67).—One specimen in pre-*Orbulina* Telisa; noted in lower Palembang of other localities.

ACKNOWLEDGMENTS

I wish to take this opportunity of extending my gratitude to Dr. R. N. Nelson and Mr. F. C. Sealey of the American Overseas Petroleum Company for permission to publish the results of this study. Acknowledgment is given in the text to those contributing comments on the stratigraphic distribution of *Orbulina universa* in various parts of the world.

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DISCRIMINATION OF LATE UPPER DEVONIAN[1]

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ABSTRACT—The general problem of the late Upper Devonian in western North America is discussed. Certain outstanding local sections, including some from new boreholes, are described with reference to stratigraphy and paleontology. Seventeen new species of brachiopods of value as guide fossils are described. It is concluded that the late Upper Devonian consists of great thickness of post-*Cyrtospirifer whitneyi* deposits marked by species of *Cyrtiopsis*, and that the Devono-Mississippian boundary is the contact between these *Cyrtiopsis*-bearing strata and the overlying thin, fissile, black shale bed known in western Canada as the Exshaw formation.

OUTLINE OF THE PROBLEM

IN WESTERN North America, there are as yet no recorded criteria to mark distinctively the late Upper Devonian deposits or to differentiate among them. Though certain formations may have been separated, and certain others correlated by the application of astute supposition, there has been no general achievement of results by the use of unassailable paleontological reasoning. However the problem of discriminating the late Upper Devonian may have been regarded prior to the year 1948, it took on in that year, as a consequence of discoveries relating to the geological composition of the central Alberta oilfields, a somewhat augmented importance. As increasing quantities of fossil collections were received by the writer's office in 1948 and succeeding years, plans were made to work toward the solution of the problem which they brought with them.

Any attempt at refining the correlation of the late Devonian in the West comes quickly to grips with the impossibility of correlating, with any genuine consciousness of telling the truth, the *Cyrtospirifer* faunas of the Middle West with the various "*Spirifer*" *whitneyi*-like forms in the Rocky Mountain region which, though long since named and (with respect to some) fairly thoroughly described, are almost unknown as regards their systematic place in the spiriferid family and their true position in the chronological scheme. Though general Devonian correlations attempted in recent years have, by reasoning from the evidence of other fossils, been able to place the "*whitneyi*"-bearing Ouray and Percha formations somewhat higher in the column than Chemung, they still fail to accomplish exact correlation with the "*whitneyi*"-bearing Three Forks or possible Canadian equivalents; they still fail to find the meaning of the "*Cyrtospirifer*" element in the faunas; they still offer no explanation for severing the formerly acceptable correlation of "*Cyrtospirifer*" forms of *C. animasensis* affinity with *Cyrtospirifer whitneyi* proper as it occurs in Iowa.

Another persistent question concerns the separation of Devonian from Mississippian deposits in the Rocky Mountain region, and with that question depends another, namely, the correlation of the black shales that in some states are labeled Mississippian, in others Devonian. In western Canada, this black shale is the Exshaw formation, currently classed as Devonian, but not, even in the most generous interpretation, soundly correlated, for recently it has been placed as equivalent of the Three Forks formation which is already known to be an incongruous group of deposits and faunas. A black shale very similar to Exshaw occurs in the Three Forks and in the Percha shale sections. The chronological position of these black shales has been much disputed.

Uncertainties of the sort outlined in the last few paragraphs hindered an early understanding of the stratigraphic classification and correlation of the deposits of the

[1] Approved for publication by Imperial Oil Limited, Toronto, Canada.

newly discovered central Alberta oilfields. One of the petroleum-bearing zones, locally and temporarily designated as D_1, and supposed to form the top of the Devonian System, yielded fossils which were at first correlated with Chemung. Several hundred feet lower, another fossil assemblage in quite different deposits seemed very obviously of Chemung age. This might have been merely the confusion of "*Cyrtospirifer*" with *Cyrtospirifer;* but, as discovery proceeded, Kinderhook species were collected from D_1, and true Kinderhook faunas in some sections over 1000 feet higher than D_1. There appeared to be mixing of diversely correlatable fossils in one stratum—a suggestion that ought to engender suspicion. Also, there appeared to be the possibility of species with unbelievably long stratigraphic ranges—a definitely unlikely possibility in the rapidly evolving Spiriferidae.

When no more than a rough and ready interpretation is made of such facts, some of the paleontologist's conclusions may in due course stand opposed to correlations obtained from unquestionable subsurface lithological evidence; and if such conflict arises too often or stands unreconciled too long, the paleontologist's work will no longer inspire confidence. The work reported in this article has been repeatedly tested for accuracy by comparison with results obtained by other investigators whose studies were based on lithology, and it is felt that these precautions now make it possible to place sound criteria on record.

The inquiry returns, therefore, to an examination of individual geologic columns and their fossils at significant Upper Devonian localities. The method adopted here is in the main that of demonstrating the existence of a considerable magnitude of deposits between the highest acceptedly correlated Upper Devonian (Chemung correlatives) and lowest admitted Mississippian (early Kinderhook correlatives). It is hoped to make the tracing-out and the analytical dissection of this group of deposits sufficiently critical to break the impasse, and to construct a system of correlations that will not merely be in accord with the best results obtained by non-paleontological methods, but will make it possible to discriminate very positively and exactly the late Devonian at least throughout western North America.

EVIDENCE OF AMERICAN LOCALITIES

All too little fossil material from localities in the Rocky Mountain states has been reposited in the writer's office. It has been necessary, therefore, to make use largely of published descriptions.

Some important localities center around Lake Valley in southern New Mexico, where the late Upper Devonian is known as the Percha shale. From Hillsboro, Kingston and Rhodes Pass, the following fauna is known (Stainbrook, 1947):

Camarotoechia sobrina Stainbrook
Paurorhyncha cooperi Stainbrook
Paraphorhynchus perchaensis Stainbrook
Shumardella glabraventra Stainbrook
Strophopleura notabilis Kindle
Cyrtiopsis animasensis Girty
C. kindlei Stainbrook
C. breviposticus Stainbrook
Syringospira prima Kindle
Brachythyris putilla Stainbrook
Tylothyris novamexicana Stainbrook
Torynifer spinosus Kindle
Cleiothyridina reticulata Stainbrook
C? coloradensis Girty
C? transversa Stainbrook

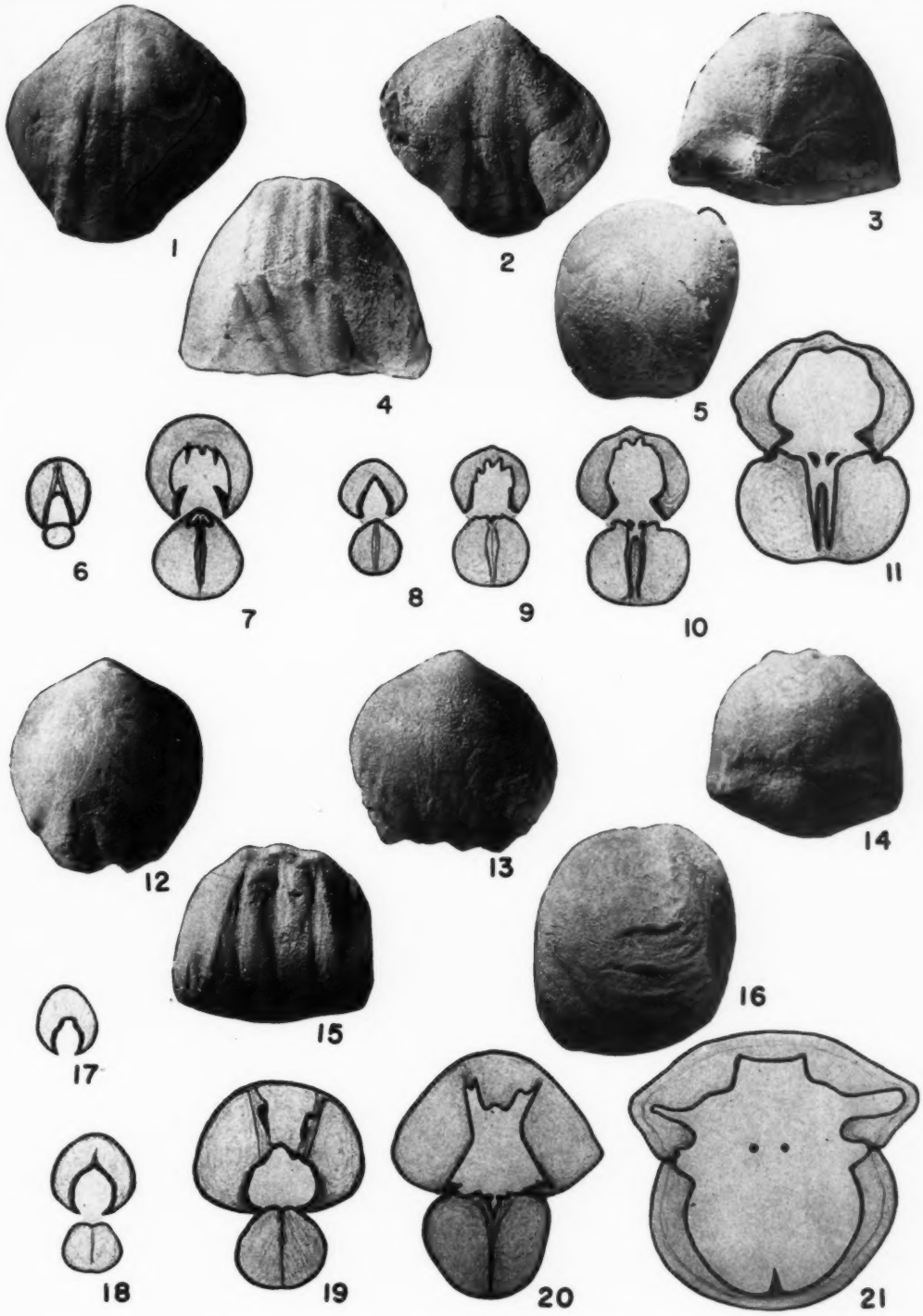
EXPLANATION OF PLATE 70

FIGS. *1–5, 8–11—Leiorhynchus carya* Crickmay, n. sp. Fig. *1*, Holotype, dorsal aspect, ×1.6; *2*, holotype, ventral aspect, ×1.6; *3*, holotype, posterior aspect, ×1.6; *4*, holotype, anterior aspect, ×1.6; *5*, holotype, left lateral aspect, ×1.6; *8–11*, paratype, successive sections across the rostral region, ×5. (p. 599)

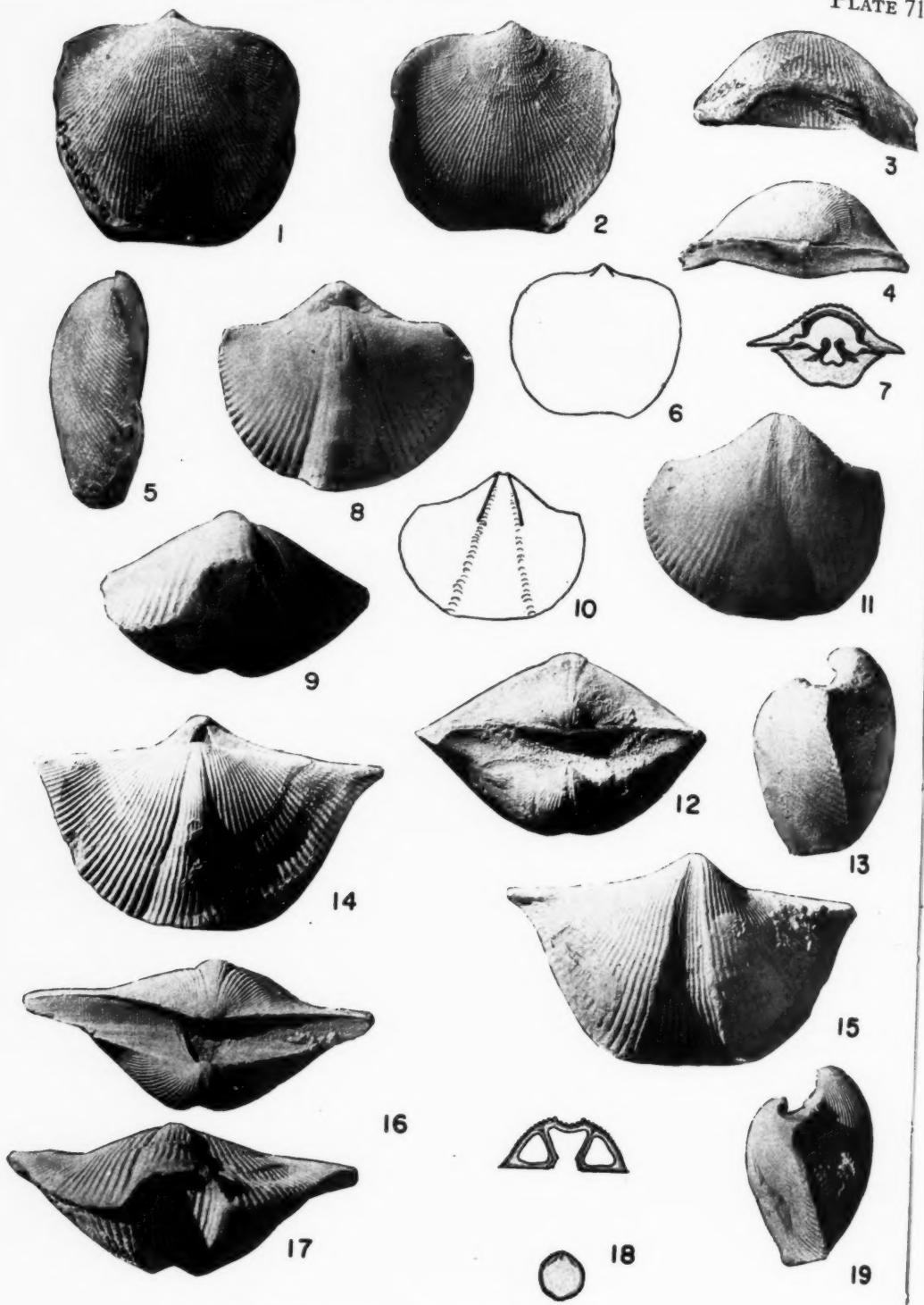
6–7—Leiorhynchus castanea Meek, from Horn River, N.W.T., Canada, inserted for comparison, successive sections across the rostral region, ×5. (p. 599)

12–21—Leiorhynchus basilicum Crickmay, n. sp. Fig. *12*, Holotype, dorsal aspect, ×1.5; *13*, holotype, ventral aspect, ×1.5; *14*, holotype, posterior aspect, ×1.5; *15*, holotype, anterior aspect, ×1.5; *16*, holotype, left lateral aspect, ×1.5;

17–21, paratype, successive sections across the rostral region; Fig. *17*, *18*, ×5; *19*, ×4; *20*, ×3.7; *21*, ×2.6. (p. 600)



Crickmay, Upper Devonian Brachiopods



Crickmay, Upper Devonian Brachiopods

Composita bellula Stainbrook
Schellwienella percha Stainbrook
Leioproductus coloradensis Kindle
L. plicatus Kindle
Avonia defessa Stainbrook
Heteralosia nupera Stainbrook
Planoproductus hillsboroensis Kindle
Bispinoproductus varispinosus Stainbrook
Pustula praecedens Stainbrook
Krotovia spinigera Kindle
K. praecursor Stainbrook
Echinoconchus laminatus Kindle
Buxtonia singularis Stainbrook
Schizophoria australis Kindle
Dielasma coriforme Stainbrook

It has been shown that *Syringospira prima*, where found in the Martin limestone of Arizona, belongs to a fauna that occurs higher, and is therefore later, than the Chemung element in the Martin with "*Theodossia*" cf *T. hungerfordi*, *Indospirifer*, etc. *Syringospira prima* has been compared with "*Cyrtia*" *alta* of the Amity shale in the lower part of Conewango Stage, a step forward in the correlation of Rocky Mountain "*Cyrtospirifer*"-bearing deposits, however short it may fall of a finally accurate correlation. Unfortunately, it makes no use of the evidence of the "*Cyrtospirifer*" species, ranged in the list above under *Cyrtiopsis*, the definitive element in the fauna. The resemblance of such forms as *Cyrtiopsis kindlei* to *Cyrtospirifer* is external and megascopic only. The long, thin, curved, subparallel dental lamellae of *C. kindlei* are typical of *Cyrtiopsis* and are very different from the short, straight, divergent lamellae of *Cyrtospirifer*. There are also notable differences in apical and umbonal callus, and in manner of ornament and microornament. *Cyrtiopsis kindlei* and *C. animasensis* have no connection whatever with the *Cyrtospirifer* sp. occurring in the Sly Gap shale (of late Frasnian Age in the same region).

With the chronological position of *Cyrtiopsis* in question, the obvious resort is to the original locality of the type species. Unfortunately, neither this nor any other of the original group of Chinese species was recorded as from a locality or a geological formation other than Upper Devonian, nor were their associations with any other fossils noted. It will be possible in the course of this study to come to a close approximation of the chronological range of *Cyrtiopsis*, but at this point it will be sufficient merely to state that the Percha shale falls within this range and that, in comparison with many new Canadian species, *C. kindlei* and *C. animasensis* are highly evolved and therefore presumably late forms of the genus.

The suggestion has been made, and must be examined, that the Percha is Mississippian. Not all the arguments on this question are equally impressive. For instance, Rhynchonellidae have too little character to be given much weight; and as for *Tylothyris*, though the genus in the strict sense is peculiarly Mississippian, *T. novamexicana* is too imperfectly connected with the genus for one to be sure that it is not a mere homoeomorph and accordingly of uncertain age. On the other hand, *Strophopleura*, even if we shall show later in this article that it appeared in the late Devonian elsewhere, occurs at the New Mexico localities only in the Percha shale and the superjacent Mississippian Caballero limestone, and is therefore of the nature of a connection with the Mississippian. *Torynifer*, *Cleiothyridina* and *Composita* are all fair confirmatory evi-

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EXPLANATION OF PLATE 71

FIGS. *1–7*—*Atrypa cosmeta* Crickmay, n. sp. Fig. *1*, Holotype, dorsal aspect, ×1.5; *2*, holotype, ventral aspect, ×1.5; *3*, holotype, anterior aspect, ×1.5; *4*, holotype, posterior aspect, ×1.5; *5*, holotype, left lateral aspect, ×1.5; *6*, holotype, outline and disposition of lamellae, ventral aspect, ×1; *7*, paratype, section across the rostral region, ×3. (p. 600)

8–13—*Cyrtospirifer alexandrae* Crickmay, n. sp. Fig. *8*, Holotype, dorsal aspect, ×1.5; *9*, holotype, anterior aspect, ×1.5; *10*, holotype, outline and disposition of lamellae, ventral aspect, ×1; *11*, holotype, ventral aspect, ×1.5; *12*, holotype, posterior aspect, ×1.5; *13*, holotype, left lateral aspect, ×1.5. (p. 602)

14–19—*Cyrtospirifer charitopes* Crickmay, n. sp. Fig. *14*, Holotype, dorsal aspect, ×1.5; *15*, holotype, ventral aspect, ×1.5; *16*, holotype, posterior aspect, ×1.5; *17*, holotype, anterior aspect, ×1.5; *18*, paratype, section across the rostral region, ×3; *19*, holotype, left lateral aspect, ×1.5. (p. 602)

dence for Mississippian age. Possibly the best paleontological testimony lies among the numerous Productidae most of which are of Mississippian relationship. Of these, *Avonia*, *Buxtonia*, *Pustula*, *Krotovia*, and *Echinoconchus* are of known Carboniferous and later occurrence; they have not been known from the Devonian. *Leioproductus*, *Planoproductus*, and *Bispinoproductus* have hitherto been known only from Percha and Ouray formations, and hence nothing can be said of their ranges. In general, a profusion of Productidae is more characteristic of post-Devonian time. On the other hand, it might reasonably be asked how is it possible to know what is characteristic of post-Devonian in distinction from late Devonian before the latter has been positively demonstrated on independent grounds.

The fauna occurs in the upper half of the Percha formation (Bella member), a deposit of "yellow" and green shales up to 60 feet thick. This overlies the lower Percha, a similar thickness of grey to dark, silty shales containing very few fossils, a species of *Leiorhynchus* in one section proving its Devonian age. The uppermost part of the upper Percha is a distinct and very significant deposit, generally less than 10 feet thick, of black fissile shale with phosphatic lumps. This is separated from the fossiliferous Percha below it by an eroded and slightly irregular contact. It is overlain by 20 to 60 feet of soft gray silty limestone, the Caballero formation, with a Kinderhook fauna:

Strophopleura novamexicana Miller
Spirifer louisianensis Rowley
S. gregeri Weller
S. vantuyli Moore
Cleiothyridina prouti Swallow
Avonia boonensis Branson
Dictyoclostus fernglenensis Weller
Echinoconchus chouteauensis Branson etc.

which in turn is overlain by the Mississippian Lake Valley formation.

The Ouray fauna of southwest Colorado is essentially similar to the Percha. It includes most of the same species with, in addition, *Paurorhyncha endlichi* Meek and *Cyrtiopsis conicula* Girty. This fauna occurs in dark limestone, 40 to 50 feet thick, and is overlain by lighter-colored limestones which, 150 feet higher, contain a Kinderhook fauna. The correlation is, of course, the same as that of the Percha.

An important late Devonian section is that at Three Forks in southwestern Montana. The stratigraphy and paleontology of this area were described by Haynes (1916). A more critical and exact interpretation (unpublished) was presented by R. D. Holland at the 1951 meeting of the Society of Economic Paleontologists and Mineralogists.

The Lodgepole limestone member of the Madison formation, with typical Kinderhook fauna, rests upon the Sappington sandstone and limstone, 60 to 80 feet thick, containing *Syringothyris carteri* Hall. This lies upon 1 to 19 feet of black shale without megafossils which in turn succeeds 1 to 10 feet of dark-gray limestone and 120 to 200 feet of green shale, minor limestone, and argillaceous dolomite. These form the Three Forks formation as it is currently limited. The upper limestone bed and associated shale yields the following fauna:

Camarotoechia contracta Hall (?)
Leiorhynchus dunbarense Haynes
L. madisonense Haynes
L. gibbosum Haynes
L. ventricosum Haynes
L. jeffersonense Haynes
L. mesacostale Hall (?)
L. cf. L. laura Billings (?)
Strophopleura raymondi Haynes
Cyrtiopsis monticola Haynes
C. animasensis Girty (?)
C. gallatinensis Haynes
C. n. sp.
Crurithyris sp. (="*Ambocoelia gregaria*," Raymond)
Cleiothyridina devonica Raymond
Composita sp.
Schuchertella chemungensis var. *arctostriata* Hall
Leioproductus coloradensis Kindle
L. plicatus Kindle
Krotovia spinigera Kindle
Echinoconchus laminatus Kindle
"*Productella*" cf. *P. depressa* Kindle
"*P.*" cf. *P. hirsuta* Hall
"*P.*" cf. *P. hirsutiformis* Walcott
"*P.*" cf. *P. subaculeata* Walcott
"*P.*" cf. *P. subalata* Hall (?)
"*P.*" cf. *P. arctirostrata* Hall
Schizophoria australis Kindle
Rhipidomella vanuxemi Hall
"*Orthoceras*" *montanense* Raymond
Geisonoceras normale Raymond
G. accelerans Raymond
Platyclymenia americana Raymond
P. polypleura Raymond
Prolobites simplex Raymond
"*Tornoceras*" *crebriseptum* Raymond
"*T.*" *douglassi* Raymond
Various pelecypoda, etc.

The *Syringothyris carteri* fauna is one of the Rocky Mountain variants of the Kinderhook group of faunas. It is definitely Mississippian and is younger than earliest Mississippian. It is wrong to place it in the Devonian (Andrichuk, 1951).

The black shale in the Three Forks (not the "black shale" of Sloss and Laird, 1947, which lies well up in the Mississippian) seems beyond question correlative with the similar and corresponding topmost member of the Percha formation. Both seem to be equivalents of the formation which in Canada has been distinguished under the name Exshaw, a black shale lying upon *Cyrtiopsis*-bearing deposits and overlain by beds with a Kinderhook fauna. The writer suggests that it would be well if this black shale were separated from Three Forks, and distinguished as a basal member of the Sappington formation to which it is probably much closer in age.

The *Cyrtiopsis monticola* fauna has much in common with the Ouray and Percha. Though the described *Cyrtiopsis* species have different names in each locality, many undescribed specimens can be matched from the two districts. Many of the productids are identical; possibly more would prove identical if the Three Forks specimens were viewed with as critical an examination as Stainbrook has given the Percha. *Strophopleura raymondi* is close to *S. notabilis*. The leiorhynchoids and the mollusks bear the least resemblance to any element in the Percha, but these may perhaps be forms peculiar to a limited local environment at Three Forks, or the differences may be the effect of latitude rather than that of age. The similarities are sufficient to encourage the opinion that the Three Forks formation is probably in part equivalent to the Ouray and Percha. Any other correlation must, in face of the faunal similarity, accept a heavy burden of proof.

Correlation on a broader scale has already been attempted on the basis of the goniatites. A similarity with the Oberdevon III or *Prolobites-Platyclymenia* stage of western Germany has been claimed. This would be in effect a correlation with the Chemung which, in view of the dissimilarity of the brachiopods, is obviously too low in the column to be correlative with the Three Forks.

The Three Forks species were very incompletely described. No types were designated. Under the circumstances, though the names are unquestionably available and must be used, they cannot be applied critically in any exact work until a new study has been made of the type material. Nonetheless, the species of *Cyrtiopsis* in the fauna are, like those of the Ouray and the Percha, late forms of the genus. They are comparable with the species in the uppermost zone in the Canadian succession.

Deposits below the Three Forks in Montana, as in the southern Canadian plains, seem not to be fossiliferous above the zone of "*Spirifer argentarius*," and therefore can not well contribute to a discussion of correlation of the late Devonian.

EVIDENCE OF CANADIAN LOCALITIES

We may now deal with the evidence provided by western Canadian localities from which new fossil material is being regularly received in the writer's office. With regard to this, the only limitation is that imposed here and there by the necessity of respecting the confidential nature of certain information possessed by private corporations.

The best known localities of late Devonian strata are those of the vicinity of the Bow River Gap and Banff, Alberta; of these the type locality of the Exshaw formation, described by Warren (1937) as "on a creek a mile east of the town of Exshaw," will best serve the purpose. Here, several hundred feet of argillaceous limestones of the Banff formation has produced the following from among the local fauna:

Dictyoclostus cf. *D. burlingtonensis* Hall
D. fernglenensis Weller
Linoproductus cf. *L. ovatus* Hall
Spirifer albapinensis Hall & Whitfield
S. cascadensis Warren
S. cf. *S. striatiformis* Meek
Cleiothyridina glenparkensis Weller
C. lata Shimer.

These strata lie upon 33 feet of black fissile shale, the Exshaw formation (Warren, 1937) at "the very top" of which (as well as in the lowest few inches of superjacent limestone) occur:

Lingula cf. *L. melie* Hall
Camarotoechia sp. indet.
Allorisma? two species
Cycloceras sp. indet.

Protokionoceras?
"Tornoceras cf. *T. uniangulare* (Conrad)"

The Exshaw shale lies with a slightly irregular and rubbly contact on the Palliser limestones and dolomites with several *Cyrtiopsis* faunas in the upper 600 feet, one of which in the uppermost 50 feet includes:

Camarotoechia banffensis Warren
C. shimeri Warren
Leiorhynchus cascadensis Warren
Cyrtiopsis monticola Haynes
C. gallatinensis Haynes
C. animasensis Girty
C. sp.
"Athyris" cf. *A. angelica* Hall
Schuchertella girtyi Shimer
Leioproductus coloradensis Kindle
L. plicatus Kindle

From the lower *Cyrtiopsis*-bearing zones no good specimens are at hand.

Of the three faunas cited, that above the Exshaw is obviously a western variant of one of the Kinderhook faunas. No special discussion of it is necessary. The fauna found in the top of the Exshaw has been regarded as Upper Devonian on the basis of the supposed *"Tornoceras cf. T. uniangulare."* In view of the fact that these fossils occur higher stratigraphically than the *Cyrtiopsis* zones, it is quite plain that they cannot belong to *Tornoceras* sensu stricto, much less to the species *T. uniangulare* which had disappeared from the face of the earth by early Upper Devonian time. The writer identifies his specimens of this Exshaw goniatite as *Aganides* sp. close to *A. discoidalis* Smith, and dates the formation as earliest Mississippian.

The *Cyrtiopsis* fauna immediately below the Exshaw is similar to the faunas of the Three Forks and Ouray. The species of *Cyrtiopsis* and *Leioproductus* are definite links with the more southerly localities with which correlation (and an equally late Devonian date) seems to be indicated. The forms commonly referred to *Athyris* in the western late Devonian are species of *Cleiothyridina.*

In the Alberta Plains the earliest (though at the time unrecognized) discovery of *Cyrtiopsis* was made in Imperial Youngstown No. 1 borehole, Section 2, Township 30, Range 9, west of the 4th Meridian. From 3402 to 3430 feet in this hole are greenish sandy limestones and shales with a Kinderhook fauna:

Camarotoechia cf. *C. allani* Warren
Leiorhynchus cf. *L. carboniferum* Girty
Spirifer cf. *S. platynotus* Weller
Tylothyris, n. sp. aff. *T. clarksvillensis* Weller
Avonia sp. indet.
Rhipidomella sp. indet.
Syringothyris sp.

They overlie one foot of black fissile shale with *Orbiculoidea* sp. and conodonts, correlated with the Exshaw formation, which in turn, from 3431 to 3457 feet, overlies a green shale with:

Camarotoechia cf. *C. sobrina* Stainbrook
Strophopleura sp.
Cyrtiopsis hiraethlynae n. sp.
Crurithyris youngstownensis n. sp.
Schellwienella sp.
Leioproductus cf. *L. coloradensis* Kindle.

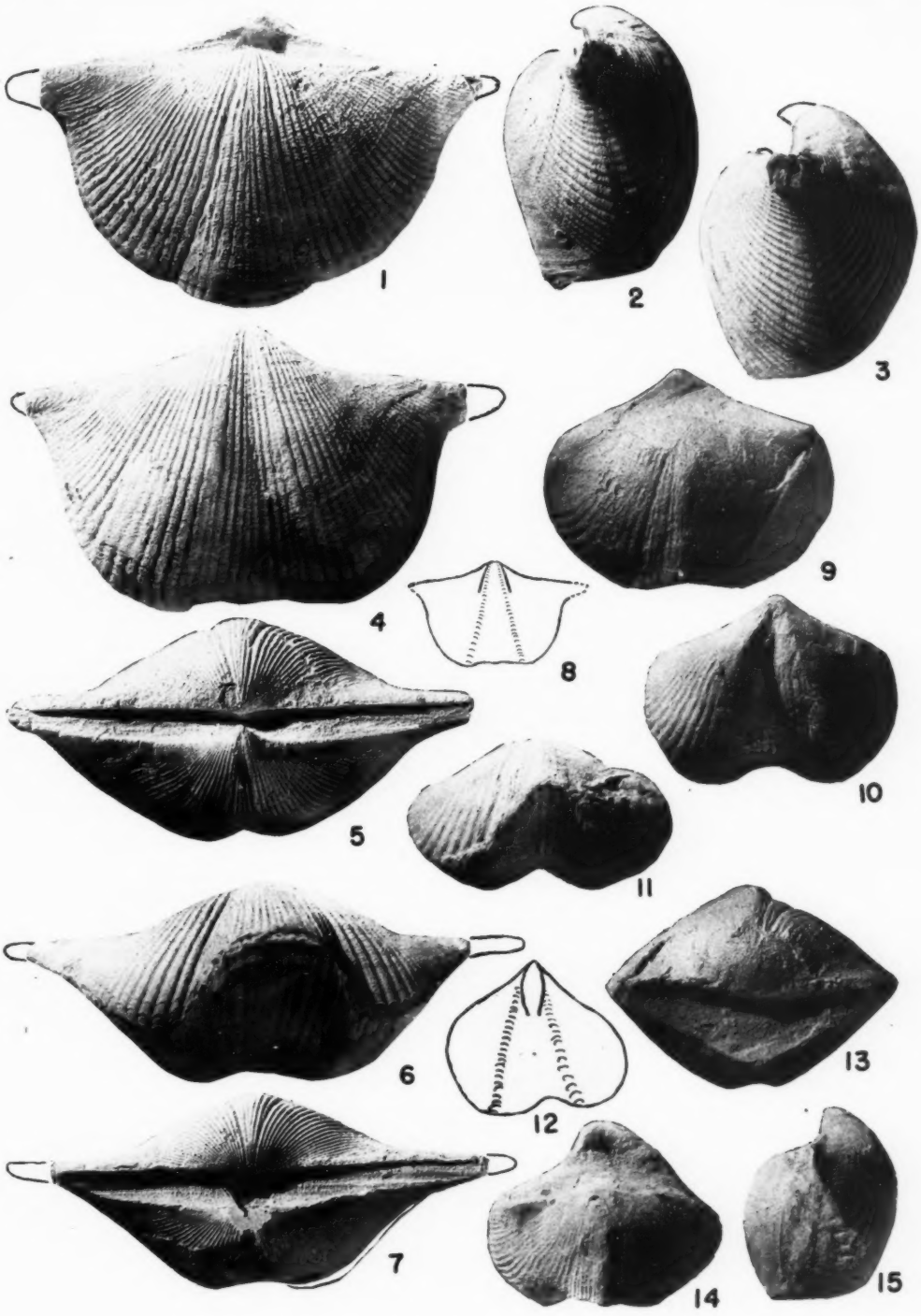
Below this is a considerable thickness of evaporites and other sediments containing no recognizable fossils.

The *Camarotoechia* of the fauna is close to the Percha species. The *Crurithyris* is identical with the form at Three Forks which Raymond called *Ambocoelia gregaria* Hall. *Cyrtiopsis hiraethlynae* may be represented at Three Forks among the forms that have been included with the protean *C. monticola.* The specimens of *Leioproductus* may be identical with *L. coloradensis.*

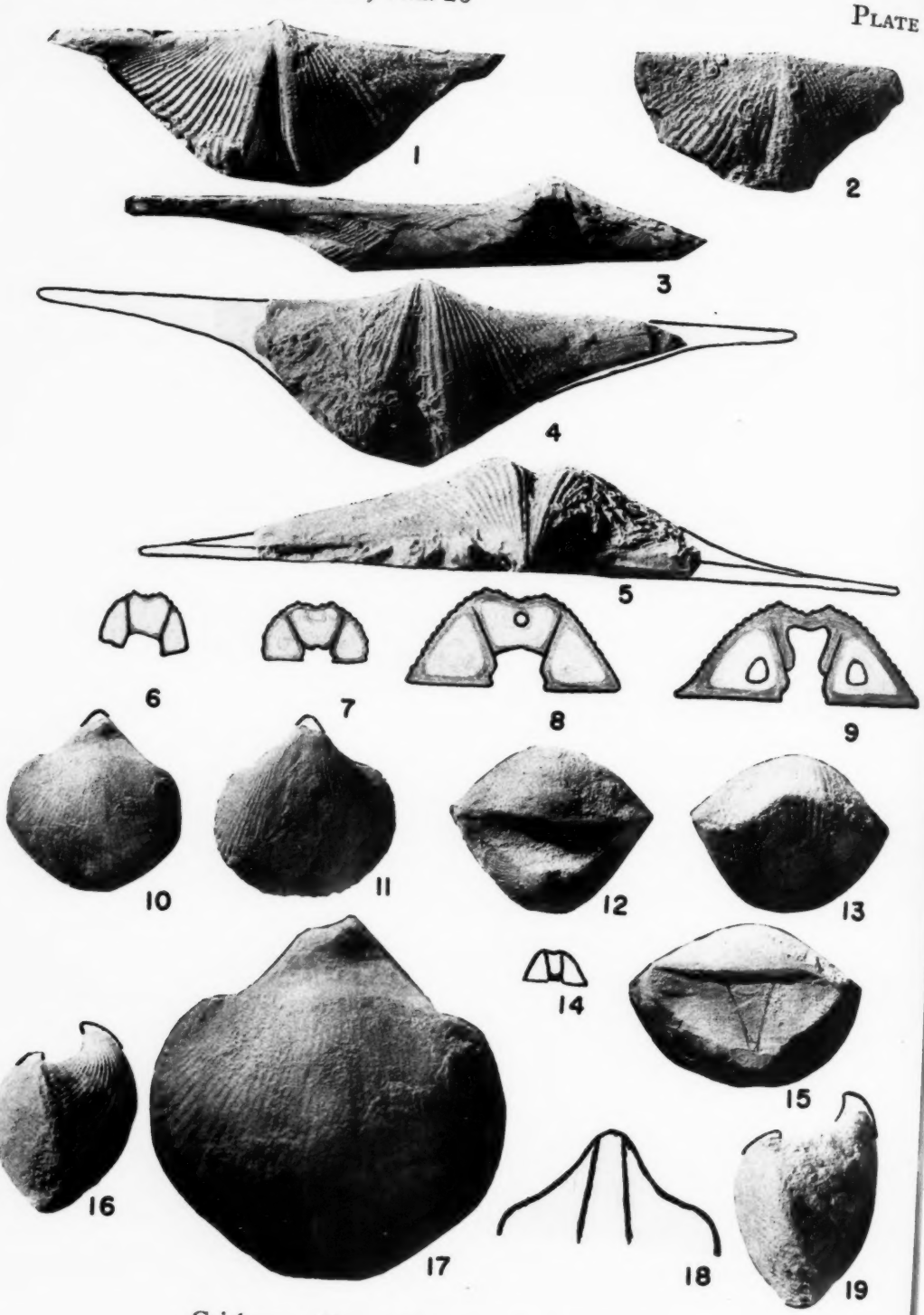
EXPLANATION OF PLATE 72

FIGS. *1–8*—*Cyrtospirifer thalattodoxa* Crickmay, n. sp. Fig. *1,* Holotype, dorsal aspect, ×1.4; *2,* holotype, left lateral aspect, ×1.3; *3,* paratype, left lateral aspect, ×1.3; *4,* holotype, ventral aspect, ×1.4; *5,* holotype, posterior aspect, ×1.5; *6,* paratype, anterior aspect, ×1.4; *7,* paratype, posterior aspect, ×1.4; *8,* holotype, outline and disposition of lamellae, ventral aspect, ×.6. (p. 601)

9–15—*Cyrtiopsis nahanniensis* Crickmay, n. sp. Fig. *9,* Holotype, dorsal aspect, ×1.6; *10,* holotype, ventral aspect, ×1.5; *11,* holotype, anterior aspect, ×1.6; *12,* holotype, outline and disposition of lamellae, ventral aspect, ×1; *13,* holotype, posterior aspect, ×1.6; *14,* paratype, dorsal aspect, ×1.5; *15,* holotype, left lateral aspect, ×1.5. (p. 603)



Crickmay, Upper Devonian Brachiopods



Crickmay, Upper Devonian Brachiopods

The correlation with the type Three Forks is very close, hence with the zone of very late *Cyrtiopsis* exemplified by *C. animasensis*.

A comparable occurrence of the late Devonian is known in Imperial Stirling No. 1 borehole, in Section 15, Township 7, Range 19, west of the 4th Meridian. Here, argillaceous limestone, at 4724 feet and deeper, contains *Tylothyris* aff. *T. clarksvillensis* Winchell and *Linoproductus* sp. It lies upon 5 feet of black shale with *"Tornoceras"* sp. which rests upon 50 feet of green shales and limestones with *Cyrtiopsis* sp. The upper fauna is Kinderhook. The *"Tornoceras"* is the form which occurs at Exshaw. The *Cyrtiopsis* is comparable with specimens from Three Forks, Montana. The 50 feet of green shales and limestones include 20 feet of black shales, not altogether unlike the Exshaw formation though not correlative. The whole is underlain by thick Potlatch evaporites.

The boreholes of Leduc oilfield and environs discovered several occurrences of supposed late Devonian fossils in the upper 30 or 40 feet of the D_1 zone. Imperial Leduc No. 2 in Section 16, Township 50, Range 26, west of the 4th Meridian, produced from this zone, between 4469 and 4497 feet:

"Leiorhynchus" n. sp.
Spirifer eudoxus n. sp.
Crurithyris sp.
Avonia aff. *A. blairi* Miller
Rhipidomella sp.

Among the first imperfect specimens recovered, the *Spirifer* was mistaken for *Cyrtospirifer*, an interpretation which caused nothing but confusion. The fauna is now known, from better prepared material to be Kinderhook, not Devonian. Since it lacks all typical early Mississippian elements such as *Tylothyris* aff. *T. clarksvillensis*, this is probably somewhat later than the earliest Kinderhook fauna. The presence of *Avonia* aff. *A. blairi* and the relationships of *Spirifer eudoxus* confirm that correlation. Stratigraphically, D_1 limestone in the oilfield must be considered correlative with upper Banff. The lower D_1 or dolomite zone is, though unfossiliferous throughout the oilfields, no doubt late Devonian in age as will appear in due course.

A supposed Upper Devonian fossil was found in Imperial Looma No. 1, Section 10, Township 50, Range 23, west of the 4th Meridian, a few miles east of the Leduc oilfield. Directly below the Mesozoic the D_1 limestone, from 4143 to 4204 feet, yielded a fossil now listed as *Spirifer* cf. *S. striatiformis* Meek. This species was originally described from the Waverly group of Ohio, and supposed to occur also in the Chouteau of Missouri. At the Looma locality, it probably indicates late Kinderhook. The D_1 dolomite below this is unfossiliferous.

Six hundred and twenty-five feet lower in the same section, unquestioned *Cyrtospirifer* aff. *C. whitneyi* (Hall) and *Atrypa* cf. *A. devoniana* Webster were obtained from cores of green shales now known as the Ireton member. Between this and the uppermost D_1, a considerable section of uncorrelated formations occurs, in descending order:

D_1 dolomite or Wabamun formation
Graminia silt member

EXPLANATION OF PLATE 73

FIGS. *1–9—Cyrtospirifer glaucus* Crickmay, n. sp. Fig. *1*, Holotype, ventral aspect, ×1.8. The mucrones are broken off; *2*, paratype no. 1, a dorsal valve, ×1.7. Mucrones and much of margin broken off; *3*, paratype no. 2, a ventral valve, ×1.9. Shell is much broken but one mucron is entire; *4*, paratype no. 3, a ventral valve, ventral aspect with mucrones restored, ×1.5; *5*, paratype no. 3, posterior aspect, ×1.5; *6–9*—paratype no. 4, successive sections across rostral region; *6*, ×5.7; *7*, ×5.7; *8*, ×5.3; *9*, ×3.5. (p. 600)

10–19—Tenticospirifer keleticus Crickmay, n. sp. Fig. *10*, Holotype, dorsal aspect, ×1.3, outline in part restored; *11*, holotype, ventral aspect, ×1.3; *12*, holotype, posterior aspect, ×1.4; *13*, holotype, anterior aspect, ×1.4; *14*, paratype, outline of section across rostral region, ×3; *15*, paratype, posterior aspect, ×1.5; *16*, holotype, left lateral aspect, ×1.5; *17*, holotype, dorsal aspect, ×2.7; *18*, paratype, part of outline and disposition of lamellae, ventral aspect, ×1.5; *19*, paratype, left lateral aspect, ×1.7, outline in part restored. (p. 603)

Calmar "red" shale member
Nisku dolomite member.

In Imperial Ireton No. 1, in Section 10, Township 49, Range 26, west of the 4th Meridian, a few miles south of Leduc oilfield, the upper (or limestone) portion of D_1, from 4770 to 4814 feet, yielded:

Camarotoechia sp. indet.
Spirifer eudoxus n. sp.
S. zantedeschii n. sp.
Schuchertella (?) sp. indet.
Avonia sp. indet.

The relationships of the *Spirifer* species are with late Kinderhook forms. Remarks made in connection with the similar fauna in Leduc No. 2 are also applicable here.

Spirifer zantedeschii has been found 150 feet above the Exshaw shale, at 3920 to 3922 feet, in Socony Western Prairie Endiang No. 1 borehole in Section 16, Township 34, Range 15, west of the 4th Meridian, where the fauna consists of:

Fenestrellina sp.
Septopora sp.
Spirifer zantedeschii n. sp.
Avonia sp.

The Bryozoa have been examined by Dr. Madeleine A. Fritz who states that the species of *Fenestrellina* is of *Mississippian* affinity. The genus *Septopora* is peculiar to the Mississippian. The Endiang No. 1 occurrence is important in two ways: it is an additional correlation link between *Spirifer zantedeschii* and its chronological position; and it demonstrates the true stratigraphic position of *S. zantedeschii* well above the Exshaw formation.

Also, in the Imperial Ireton No. 1, at a depth many hundred feet below D_1 (see above), namely at 5672 to 5698 feet, the green shales of the Ireton formation have furnished the following fauna:

Atrypa devoniana Webster
Cyrtospirifer cf. *C. thalattodoxa* n. sp.
Nervostrophia vestita n. sp.
Schizophoria magna Fenton.

This is the typical assemblage of species of true *Cyrtospirifer* age as they occur in Central Alberta. The correlation is with the Hackberry of Iowa, Chemung of New York, or Frasnian of Western Europe.

In Imperial Eyot No. 1, in Section 28, Township 48, Range 25, west of the 4th Meridian, the D_1 limestone, from 4745 to 4758 feet, yielded:

"*Camarotoechia*" sp. indet.
Spirifer eudoxus n. sp.
Cleiothyridina sp.
Schuchertella sp.

This is a late Kinderhook fauna similar to that in Ireton No. 1. Below this, as at all other localities through the oilfields, the dolomite zone is without fossils, and therefore without any but indirect means of correlation.

A key to the correlation of the uppermost limestone of D_1 lies in the section revealed by McColl-Frontenac's Telfordville borehole in Lsd. 15, Section 20, Township 50, Range 2, west of the 5th Meridian. This hole penetrated a dolomite at the top of the Mississippian from 4955 to 4974 feet. Below that, from 4974 to 5090 feet, a pale limestone, in places buff, in others greenish, yielded throughout:

"*Leiorhynchus*" n. sp.
Spirifer eudoxus n. sp.
Avonia sp.

On the basis of faunal and lithological similarity, this is equivalent to the uppermost limestone of D_1; it is of upper Kinderhook age. At 5260 feet in dark calcareous shales *Spirifer* cf. *S. albertensis* Warren occurs. This zone, of lower Kinderhook age, does not appear at Leduc.

Still lower, between 5300 and 5425 feet, a series of shales and thin shaly limestones, without fossils, occurs in the cores. Between 5425 and 5430 feet, the very dark shale of the Exshaw formation, also without fossils, is present. A dull earth-gray limestone with *Cyrtiopsis* sp. is present between the Exshaw and the dolomite of D_1, from 5430 to 5455 feet. This obviously is the uppermost deposit that can be connected with the Devonian System.[1] It resembles only one bed in the Leduc column, the lower part of the limestone portion of D_1. If it be truly correlative with this, then obviously the boundary between Devonian and Mississippian at

[1] *Editors note:* The latest draft of Report No. 2 prepared by the American Stratigraphic Commission (Nature, Usage and Nomenclature of Time-Stratigraphic and Geologic-Time Units) recommends that the initial letter of time-stratigraphic and geologic-time units (system-period, series-epoch, stage-age) be capitalized, when used in combination to form a name (as Triassic System, Jackson Stage, Bajocian Age), except for usage of informal sort employed solely for local time-correlation. This recommendation is followed here by the editors.

Leduc is the line between the two kinds of limestone in D_1. The same bed has correlatives in the subsurface geology many miles to the northwest. Limestones very similar to it form the great part of the highest Devonian in the column revealed in the Bear Villa No. 1 near Lesser Slave Lake, and in the Imperial Normandville No. 1 in the Peace River vicinity.

Below 5455 feet in the Telfordville column lies a section readily correlated with that at Leduc, the Wabamun formation and Graminia, Calmar, Nisku and Ireton members being represented. At 6579 to 6604 feet, the Ireton shales yielded *Atrypa devoniana* Webster and *Cyrtospirifer* (?) sp. This confirms the connection with the upper Frasnian.

In Imperial Normandville No. 1, in Section 11, Township 79, Range 22, west of the 5th Meridian, about 220 miles northwest of Edmonton, below the Mesozoic, a considerable thickness of limestones and shales yielded rich faunas throughout. The full details do not concern the present study. However, one very obviously Kinderhook assemblage may be listed from the lower 400 feet, namely, from 4890 to 5410 feet:

Camarotoechia cf. *C. allani* Warren
Camerophoria sp.
Spirifer albertensis Warren
S. aff. *S. lateralis*
"Spirifer" rutherfordi Warren
Schellwienella sp.
Dictyoclostus sp.
Punctospirifer sp.
Dielasma sp.
Aganides cf. *A. discoidalis* Smith

These overlie 43 feet of silts. The silts lie upon 48 feet of black fissile shale with a brown rubbly bed at its base. This, though without fossil evidence, is correlated tentatively with the Exshaw formation.

Below the Exshaw lie several feet of limestone, from 5501 to 5512 feet, with a very significant fauna:

Strophopleura sp.
Choristites protistus n. sp.
Crurithyris cf. *C. unionensis* Weller
Schellwienella sp.
Avonia sp.
Aganides sp.

This fauna shows obvious Kinderhook affinity in four of its species. A fifth, *Strophopleura* sp. might be either latest Devonian or later. The sixth, a new species of *Choristites*, belongs to a genus that nowhere appears earlier than Avonian or Mississippian. All paleontological considerations, therefore, place this bed and its fauna in the earliest Mississippian, and it is difficult to envisage any sound theoretical reasons that could be urged to the contrary. If the conclusion is valid, it follows that the Exshaw is included within the lowest Misissippian, and it refutes all suggestion of the Exshaw formation's being of Devonian age. These considerations are not wholly in accord with lithogenetic history, however. While the Exshaw formation may be inseparable from Mississippian, the uppermost beds of the Boule and the Palliser merely continue the mode of late Devonian sedimentation within which it is difficult to indicate any significant hiatus that might be regarded as the Devonian-Mississippian boundary.

Below beds with the *Choristites* fauna in Normandville No. 1 are several hundred feet of limestone, between 5512 and 6350 feet, containing various species (some unidentified) of *Cyrtiopsis* distributed through it. In the uppermost part of it occur:

Camarotoechia cf. *C. sobrina* Stainbrook
Cyrtiopsis cf. *C. animasensis* Girty
Crurithyris sp.
Cleiothyridina sp.

The specimens of *Cyrtiopsis* in this topmost cyrtiopsian fauna, though imperfectly preserved, none the less seemed to exhibit the depth of ventral valve, the long palintrope, the twisted umbo, and the typically striate micro-ornament of *C. animasensis*. The other elements in this small fauna also strongly suggest correlation with the widespread uppermost cyrtiopsian zone.

Below this zone, various *Cyrtiopsis* fragments were too imperfect for specific identification. Several hundred feet lower, from 6032 to 6046 feet, another small but well-preserved fauna was cored:

Yunnanella cf. *Y. mesoplicata* Grabau
Cyrtiopsis normandvillana n. sp.
Cleiothyridina sp.
Chonopectus horaeus n. sp.

This remarkable assemblage is quite unique in that the Asiatic *Cyrtiopsis* is joined here by another Chinese derivative, *Yunnanella*, a costellate-plicate rhynchonellid never hitherto reported from North America. From its position in the section, this group

of species marks one of the lower, but not the lowest, of the cyrtiopsian zones.

In the same borehole, several hundred feet deeper, from 6593 to 6680 feet, gray to green shales occur with:

Tabulophyllum sp.
Cladopora sp.
Atrypa sp.
Cyrtospirifer sp.
Indospirifer sp. aff. *I. orestes* Hall & Whitfield

None of these fossils is well preserved, but the assemblage is plainly recognizable as part of the true *Cyrtospirifer* group of faunas. Its correlation is with the green shale or Ireton formation of the oilfields of central Alberta, or with Chemung or upper Frasnian, to carry the connection to greater distances. This occurrence again proves by superposition the true stratigraphic relationship between *Cyrtiopsis* and *Cyrtospirifer;* species of the former form a compact succession of zones entirely distinct from, and several hundred feet above, the latter.

The outcrop areas of Upper Devonian in the mountains southeast of Jasper offer evidence that closely parallels the testimony of Normandville No. 1. A considerable section of Banff limestones and shales contain:

Camarotoechia allani Warren
Spirifer cf. *S. striatiformis* Meek
S. albertensis Warren
"*Spirifer*" *rutherfordi* Warren
Cleiothyridina lata Shimer
Composita athabaskensis Warren
Dictyoclostus jasperensis Warren
Linoproductus ovatus Hall
Syringothyris cf. *S. hannibalensis* Swallow

This Kinderhook fauna occurs above 10 to 20 feet of fissile black shale, the Exshaw formation.

The last lies upon the thin-bedded uppermost limestones of the Boule formation. At two places, the upper 50 feet of the Boule contains a fauna which shows evidence of relationship to the Mississippian. About 1½ miles south of Cadomin, this fauna consists of:

Camarotoechia cf. *C. nordeggi* Kindle
Spirifer n. sp.
Choristites glennfoxi n. sp.

About 32 miles southwest of Nordegg, on Cline River one mile above its confluence with the North Saskatchewan, the fauna includes:

Camarotoechia cf. *C. nordeggi* Kindle
C. n. sp.
Leiorhynchus cf. *L. dunbarense* Haynes
Spirifer n. sp.
S. sp.
Choristites glennfoxi n. sp.
Schizophoria aff. *S. australis* Kindle

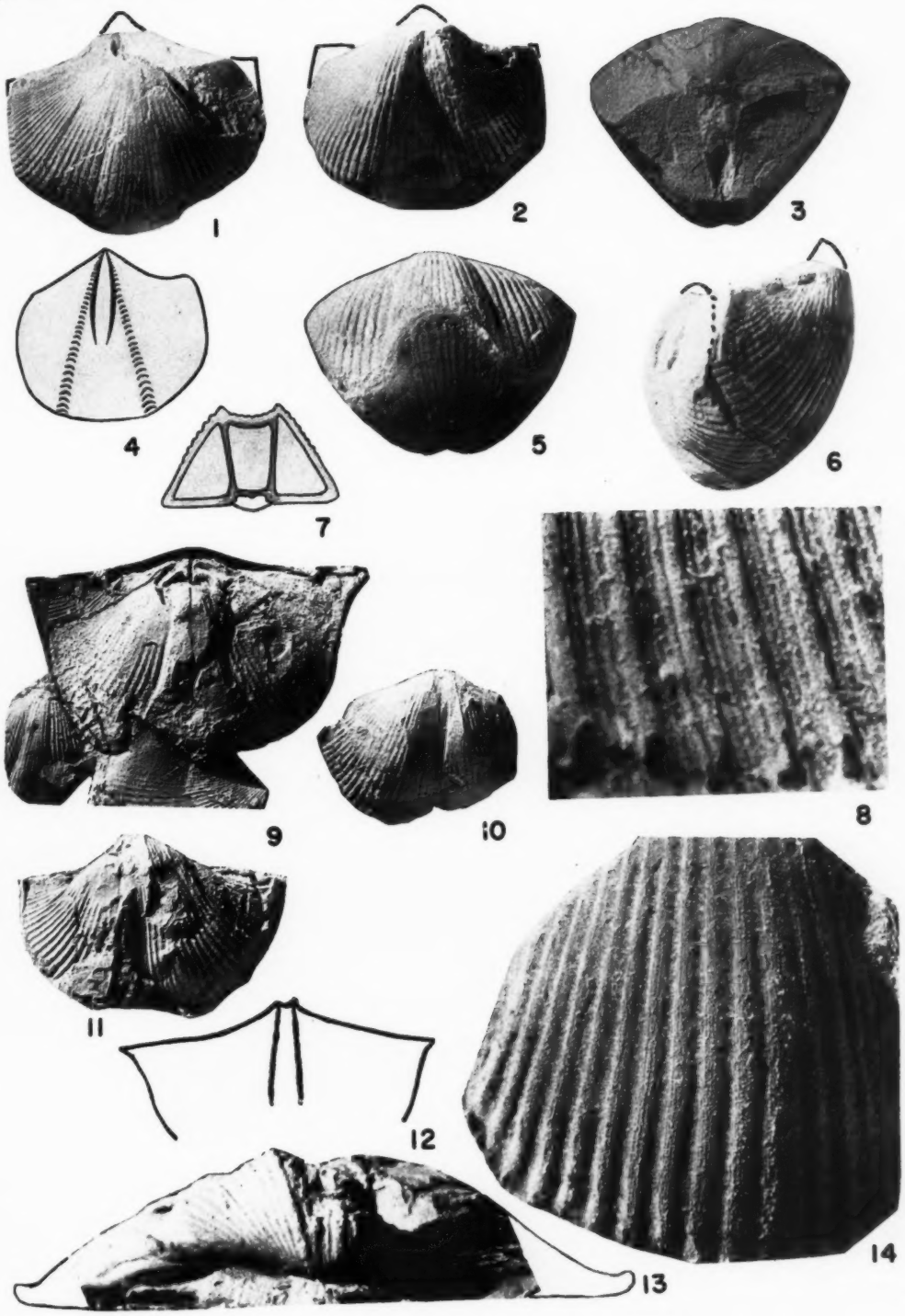
The presence of three species of *Spirifer* seems to connect these beds unmistakably with the Mississippian. The species of *Choristites* present in this zone is quite unlike the one found in Normandville No. 1, but possesses at least some of the characteristics typical of the genus, and confirms the correlation. This zone at the top of the Boule formation is roughly correlative with the zone of *Choristites protistus*, but it must not be concluded that they are necessarily exact equivalents.

Below these topmost beds, the Boule is considerably more coarsely bedded, and has faunas with *Cyrtiopsis* species. At the Deception Creek section, a locality 33 miles due east of Jasper, Alberta, the main thickness of the Boule limestone contains several cyrtiopsian zones, some with unidentified, some with obviously new species. The highest zone in this section, roughly the upper 100 feet, yields *Cyrtiopsis* cf. *C. animasensis* Girty. This is probably the close correlative of the other occurrences of that species.

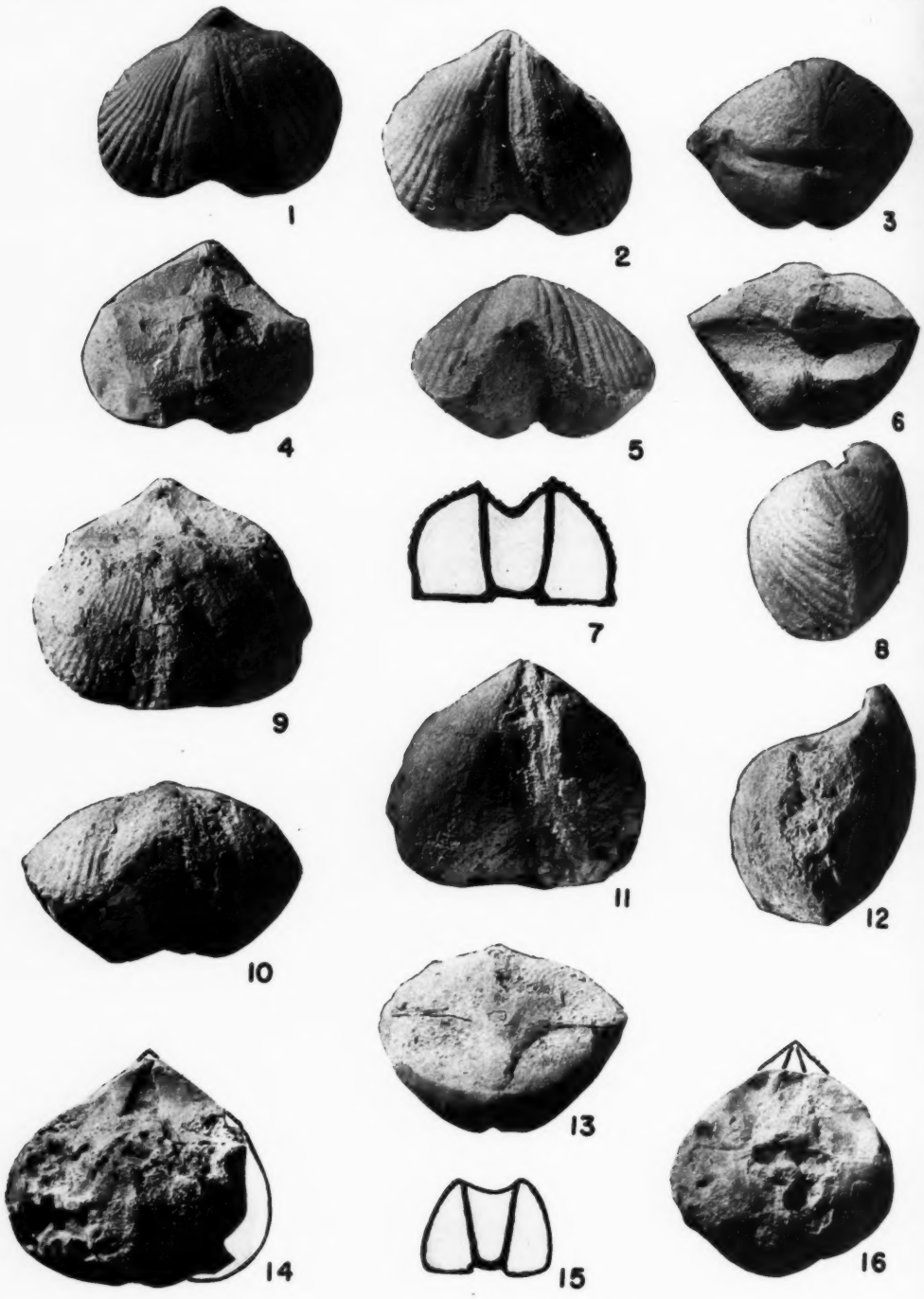
EXPLANATION OF PLATE 74

FIGS. *1–8*—*Cyrtiopsis normandvillana* Crickmay, n. sp., holotype. Fig. *1*, Dorsal aspect, ×1.7, outline in part restored; *2*, ventral aspect, ×1.6; *3*, posterior aspect, ×1.7; *4*, outline and disposition of lamellae, ventral aspect, ×1.3; *5*, anterior aspect, ×1.7; *6*, left lateral aspect, ×2; *7*, section across rostral region, ×5; *8*, impression in the rock of exterior, ×15. Costellae and radial striae. (p. 605)

9–14—*Cyrtiopsis hiraethlynae* Crickmay, n. sp. Fig. *9*, Holotype, a brachial valve with much of shell removed, dorsal aspect, ×1.6, with other shells attached; *10*, paratype no. 1, ventral aspect, ×1.5; *11*, paratype no. 2, ventral aspect, ×1.5; *12*, paratype no. 2, outline and disposition of lamellae, ventral aspect, ×1.5; *13*, paratype no. 2, posterior aspect, ×3.5; *14*, paratype no. 2, exterior, ×8. (p. 605)



Crickmay, Upper Devonian Brachiopods



Crickmay, Upper Devonian Brachiopods

Directly below this lie two zones marked by unnamed species.

Below the Boule formation, the several hundred feet of sandstones, arenaceous limestones, siltstones and shales which form the upper part of the Cheviot formation comprise at least three successive zones. The uppermost of these contains *Camarotoechia* sp. and *Composita* (?) sp. Description of these species must await future work. The next lower zone contains *Cyrtiopsis prepta* n. sp. The lowest zone contains *Cyrtiopsis mimetes* n. sp. These two species of *Cyrtiopsis* are plainly early forms of the genus. They occur in the two lowest zones of a succession of at least six zones in the cyrtiopsian group.

The lower part of the Cheviot formation, consisting mainly of limestones, contains an entirely different fauna, *Atrypa* sp. and *Cyrtospirifer* sp. indet. This, though ill-preserved, is clearly enough a true *Cyrtospirifer* fauna of Chemung Age. Here, once again, the stratigraphic relationship between *Cyrtiopsis* and *Cyrtospirifer* is evident. It is to be noted that *Atrypa* almost invariably accompanies *Cyrtospirifer; Camarotoechia*, unknown in this region in association with *Cyrtospirifer*, appears suddenly and displaces *Atrypa* completely as the companion of *Cyrtiopsis* (Warren and Stelck, 1950).

In the basal bed of the Cheviot and in the uppermost shales of the subjacent Perdrix formation occurs a fauna including *Leiorhynchus carya* n. sp. This might be of middle Frasnian, or upper Finger Lakes Age. *L. carya* is obviously derived from *L. castanea* in comparison with which it shows considerable modification. *L. castanea*, occurring in the Horn River shale, of late Middle to early Upper Devonian age, is not found in this section. At the base of the Perdrix formation occurs the fauna of *Eleutherokomma jasperensis*, which may mark the base of the Upper Devonian. Since the above was written, Warren and Stelck (Trans. Roy. Soc. Canada, XLIV, 1950, p. 68) have made the first published statement of a genuine *Cyrtospirifer* fauna in the Rocky Mountains of Canada, the locality being Eaglesnest Pass in Lat. N 53° 40′.

The *Cyrtiopsis* faunas occur in the outcrop sections in the Mackenzie River valley, Northwest Territories of Canada. At a place on the left bank of Mackenzie River, 8 miles above the mouth of North Nahanni River, and at places on the right bank opposite Root River, platy limestones with thin, pale gray-green shale interbeds and partings contain a large fauna of brachiopods and other fossils including:

Camarotoechia sp.
Leiorhynchus basilicum n. sp.
Tenticospirifer keleticus n. sp.
Cyrtiopsis nahanniensis n. sp.
Cleiothyridina sp.

This may be an early species of *Cyrtiopsis*—roughly correlative with *C. prepta* and *C. mimetes*. The deposit in which it occurs is the "*Leiorhynchus* limestones" named in early work by Hume, but very incompletely described. It is not known what beds overlie the "*Leiorhynchus* limestones" or what they immediately overlie. They occur high in the Upper Devonian section being underlain successively by:

the silty limestone with "*Cyrtospirifer*" and *Devonoproductus* and the red deposits with *Cyrtospirifer charitopes* and *Gypidula*, correlative with, but not necessarily the exact equivalent of, Calmar shale of central Alberta; the Alexandra Falls limestones and sandstones with *Cyrtospirifer alexandrae;* Hay River shales and

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EXPLANATION OF PLATE 75

FIGS. *1–8*—*Cyrtiopsis mimetes* Crickmay, n. sp. Fig. *1*, Holotype, dorsal aspect, ×1.5; *2*, holotype, ventral aspect, ×1.5; *3*, holotype, posterior aspect, ×1.5; *4*, paratype no. 1, dorsal aspect, ×1.5; *5*, holotype, anterior aspect, ×1.5; *6*, paratype no. 1, posterior aspect, ×1.5; *7*, paratype no. 2, outlines of section across rostral region, ×4; *8*, holotype, left lateral aspect, ×1.5. (p. 604)

9–16—*Cyrtiopsis prepta* Crickmay, n. sp. Fig. *9*, Holotype, dorsal aspect, ×1.5; *10*, holotype, anterior aspect, 1.5; *11*, holotype, ventral aspect, ×1.5; *12*, holotype, left lateral aspect, ×1.5; *13*, holotype, posterior aspect, ×1.5; *14*, paratype no. 1, dorsal aspect, ×1.2; *15*, paratype no. 2, outlines of section across rostral region, ×2; *16*, paratype no. 2, dorsal aspect, ×1.1; outlines in part restored. (p. 604)

limestones with *Cyrtospirifer thalattodoxa*, *C. occidentalis* Whiteaves, *Atrypa* cf. *A. devoniana* Webster, and *A. cosmeta;* and with *Eleutherokomma reidfordi* and *Cyrtospirifer glaucus* in its lowest beds; Simpson shale without ordinary megafossils; and, finally, Horn River black shale with *Leiorhynchus* cf. *L. castanea* which may be late Middle or early Upper Devonian

CORRELATION

Two primary objectives remain: first, it is necessary to gather the numerous suggested correlations together into a consistent whole; second, it is desirable to interpret on a broad basis the evidence for delimiting Devonian from Mississippian.

From what has been said it is clear that there is no mingling in any known west American locality of the earlier *Cyrtospirifer* with the later *Cyrtiopsis* faunas. Several faunas of each group are known. In full sections, *Cyrtospirifer* species occur much lower stratigraphically than *Cyrtiopsis;* the two groups of zones are separated by an hiatus.

The *Cyrtospirifer* group, marking middle Upper Devonian (=Chemung or upper Frasnian) deposits, are most fully preserved in the Mackenzie River basin of northern Canada where at least four, and possibly as many as seven, successive zones contain different species of that genus. It is likely that these zones outline most of the course of existence of *Cyrtospirifer* sensu stricto, a genus which is confined to the Frasnian Age. The writer is well aware of, and regards as mere misinterpretation, the opinion that forms belonging to *Cyrtospirifer* range through and above the Upper Devonian. The zone marked by *C. thalattodoxa* is the most widely developed, being traceable into the oilfields of central Alberta in the "Green Shale" or Ireton member, and into the Rocky Mountains on the same latitude in the lower part of the Cheviot formation. The similarity between the total fauna of this zone and the fauna of the Hackberry series[2] of Iowa leads to two conclusions: first, that the two units are in part correlative; and second, that their respective depositional areas were connected by a continuous seaway. The Hackberry series is in the main younger than the Ireton. Evidences of marine deposits of Ireton to Hackberry age are not positively known in southern Alberta, Montana or Wyoming. Their first appearance, to the south is at Sly Gap, New Mexico, where an Independence correlative occurs. The Independence is correlated with lowest Ireton.

The youngest deposits in the West bearing a species of *Cyrtospirifer* are correlatives (and in part exact equivalents) of the Calmar red shale of Leduc oilfield. These are the red beds above Alexandra Falls and the overlying limestones of Grumbler Rapid, which correlate with the upper beds of Hackberry series or the late Frasnian of Europe. Following this date, there is a gap in the record. This is not evident in southern Alberta or adjacent parts of the United States where only unfossiliferous deposits occur. However, it is very evident in the more complete sequence farther north where *Cyrtospirifer* and several other genera disappear with the red deposits and the lower beds of the "silt series," and are succeeded by the very different *Cyrtiopsis* asemblage which contains certain genera and species unknown in association with *Cyrtospirifer*. The change in faunal composition is as profound with respect to the entire preserved assemblages as it appears with respect to the few selected forms noted in this article. So abrupt a change is ordinarily thought to mean a lapse of time without deposition. This hiatus, following as it does deposits of late Frasnian age, may be expected to correspond to early Fammennian Epoch, or, in terms of the New York sequence, Canadaway time.

As with the *Cyrtospirifer* group, so with that of *Cyrtiopsis*, the earlier species appear

[2] *Editor's note:* The writer's usage of Hackberry "series" does not conform with the standard section published by the Devonian Subcommittee (G. A. Cooper, Chairman, *et al*, Correlation of the Devonian Sedimentary Formations of North America, Bull., G.S.A., 1942, vol. 53, pp. 1729–1794), and the utilization of "series" in this paper should not be construed as official sanction by the JOURNAL OF PALEONTOLOGY. Attention is directed also to the usage of Hackberry "stage" by C. H. Belanski (*in* C. L. Fenton, 1931, Studies of evolution in the genus *Spirifer:* Publications Wagner Free Inst. Sci., vol. 2, 436 pp.).

in the far north where the sections are thick, fully-developed, and replete with fossils. *Cyrtiopsis nahanniensis* is probably the earliest species of the entire series. It occurs low in the "silt zones" of the Upper Devonian. As an early species, its physical characteristics are worth noting; it is small with not very long palintrope and average strength of ornament, all primitive characteristics. On the other hand, it has the short cardinal margin, the tendency toward twisting of the umbo, the manner of ornament and micro-ornament, and the internal structure typical of its genus. Another early species of similar characteristics is *C. mimetes*. *C. prepta*, occurring only slightly higher in the section, is somewhat similar to *C. mimetes* but is advanced in respect of the notable length of the palintrope, a character which soon becomes one of the outstanding peculiarities of the genus. *C. normandvillana* has this peculiarity strongly developed, which might be expected since it occurs well above the silt zone and is, therefore, later than *C. prepta*. None of these early *Cyrtiopsis* species occurs in southern Canada or the United States. Leaving out of account a group of undescribed forms occurring somewhat above *C. normandvillana*, the late species of the genus are those of the widely developed *C. animasensis* zone at the top of the late Devonian sequence: *C. animasensis*, *C. kindlei*, *C. conicula*, *C. monticola*, *C. gallatinensis*, *C. portae*, and *C. hiraethlynae*. Everywhere, this group occurs in the uppermost deposits of demonstrably Devonian age. The group shows a maximum development of the long dental lamellae peculiar to the genus. Not all have the long palintrope characteristics of so many of the species both American and Asiatic. Several have developed, concomitantly with shorter palintrope, a remarkable homeomorphy with the very much earlier *Cyrtospirifer* a circumstance which has given rise to a great deal of misinterpretation of the affinities of the species.

Summing up, then, the span of *Cyrtiopsis* seems to embrace latest Devonian time. Assuming that *Cyrtospirifer* survived to the end of Frasnian time, and that the post-*Cyrtospirifer* hiatus corresponds to early Fammennian, the existence of *Cyrtiopsis* embraced only middle and late Fammennian, or, in New York terms, Conneaut to Oswayo. If the time seems short in comparison with so many successive evolutionary steps among these brachiopods, it is perhaps evidence for two conclusions both of which are already undertsood and well supported by other evidence: first, that the enormous and complex spiriferid family evolved with rapidity throughout the greater part of its existence; and second, that late Devonian time was an epoch of brief evolutionary expansions alternating with sudden extinction. Were the paleontological composition of the late Devonian faunas, as they occur in New York and in Western Europe, more exactly known and more fully described, the occasional references to the sequences in these places might have been given in this article in the form of very exact correlations.

On the grounds of a broad unity of faunas throughout the beds bearing *Cyrtiopsis* species, closely paralleled by a unity of lithogenetic development in the deposits, all these strata, including the highest, are retained within the upper limit of Devonian. Their maximum development is in northern Canada where the thickness of Devonian deposits of post-*Cyrtospirifer* age in places exceeds 1000 feet. Only the youngest of the six or more successive faunas within this thickness shows any resemblances to the Mississippian. The facts of these resemblances have been reviewed in the discussion of the Percha fauna. Against the interpretation that these facts indicate Mississippian age for the zone stands some paleontological reasoning not yet adequately emphasized, namely, that the highly characteristic *Cyrtiopsis* species have their genetic origins in a compact Upper Devonian group of which there is no evidence anywhere in undoubted Mississippian deposits. The latest of the *Cyrtiopsis* species in the Canadian section, *C. animasensis*, is regarded as correlative with the type occurrence of that species in Colorado. That species and its closest relatives mark the topmost beds that can be connected on any basis of sound argument with the Devonian System.

The first great change in sedimentation following the unbroken cycle of deposition through the cyrtiopsian zones is that marked by the thin fissile black shale, a truly re-

markably widespread and continuous deposit, rarely as much as 50 feet thick, and over many square miles recorded as thin as 6 inches. In southern New Mexico, it is the uppermost thin black shale of the Percha formation; in southern Montana, it is the black to "purplish-black" shale high in the Three Forks "formation" separating the *Cyrtiopsis monticola* from the *Syringothyris* fauna; in western Canada it is the Exshaw formation. This deposit has been well recognized as a formational unit in the United States everywhere but in the Rocky Mountain region where its significance is strongest. In western Canada it has come to be regarded as one of the principal markers in subsurface stratigraphy. It has been recognized in several hundred boreholes, even in some where its total thickness is less than one foot. In spite of the suggestion occasionally heard that it may be confused with earlier or later dark shales, it is seldom if ever mistaken by those who know its dark color suggestive of a bituminous character, its phosphatic lumps, its rubbly basal bed, its basal disconformity, and, locally, other marks of distinction. No *Cyrtiopsis* species has been found anywhere but below this widespread black shale. Above it everywhere there are Kinderhook fanuas. Beyond reasonable doubt, all local occurrences of it ought to be regarded as parts of one deposit. The only fossils found in the shale are of Mississippian affinity. In lithic composition, it is totally at variance with all late Devonian deposits; it initiates the mode of sedimentation of the Mississippian. For these reasons, it might reasonably be urged that the base of the black shale be taken as the line of delimitation between the two systems.

At nine localities out of ten this might be admitted as settling the question, that is, placing the Devonian-Carboniferous boundary at the top of the *Cyrtiopsis* deposits and at the base of the black fissile shales that succeed them. However, at certain places in the north, thin limestones, without *Cyrtiopsis* and with *Spirifer* species and *Choristites*, lie between the *Cyrtiopsis* beds and the thin black shales. These strata with *Choristites*, which may be known as the *C. protistus* zone, are paleontologically linked with the Mississippian rather than the Devonian. Being earlier than the black fissile shales, they are earlier than any other Mississippian beds and possibly ought to be regarded as the initial zone of that system. Though this somewhat complicates the picture from the lithogenetic point of view, at least it adds strong evidence for including the black shale within the Mississippian. On the other hand, in this question lithogenetic considerations ought, possibly, to be given more weight than paleontological; and, if that is done, the result would be to leave the *C. protistus* zone in the Devonian, and place the system boundary at the base of the black shale.

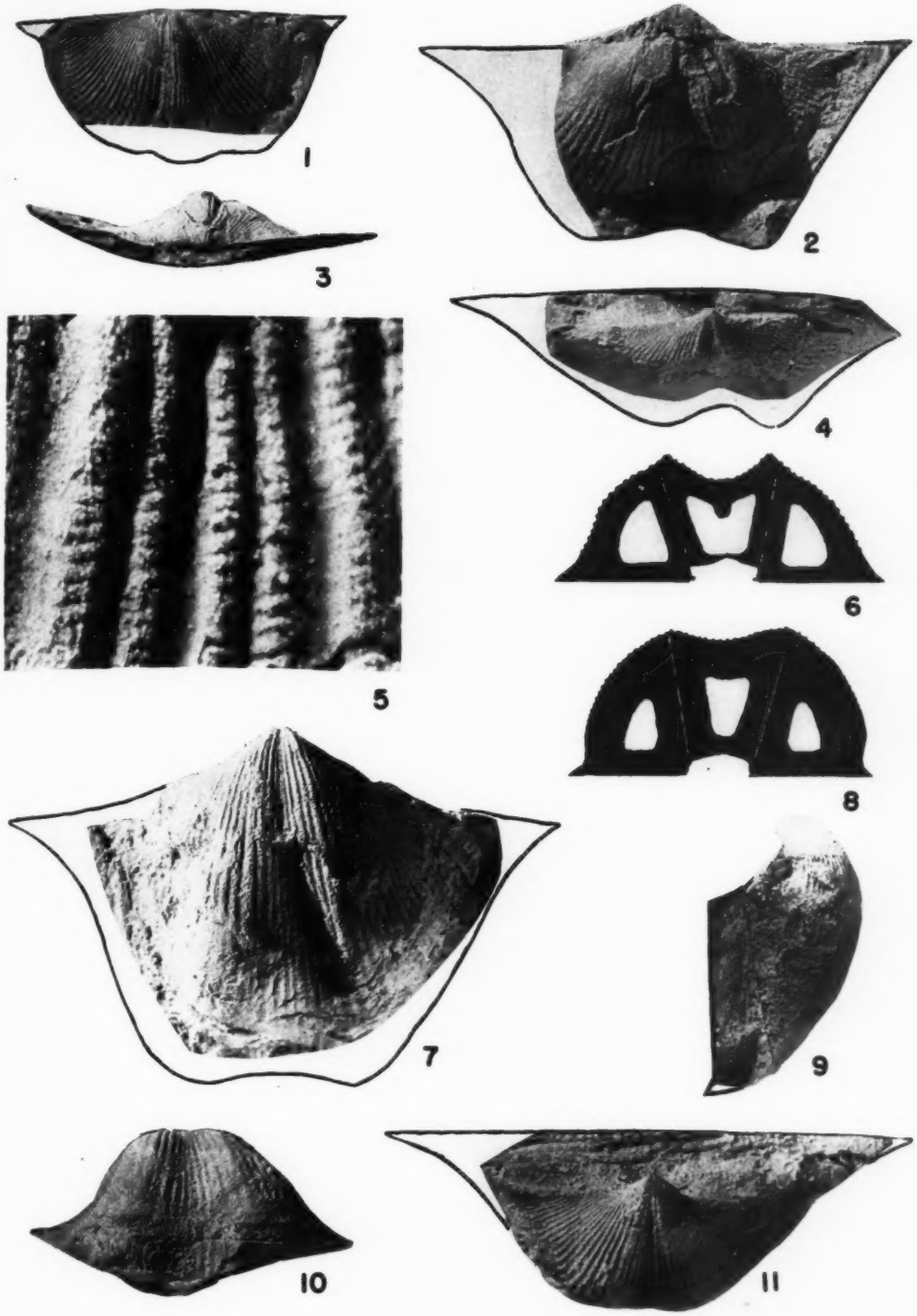
Some of the undescribed forms from the *C. protistus* zone are similar to species of the Aplington fauna of Iowa (Stainbrook, 1950), and suggest correlation with it.

Some further correlations may be attempted in the Canadian area. The total range of Upper Devonian silt in the central Alberta oilfields called also the "Silt Zone" and "Silt Series" and currently classified as Graminia and Calmar members is a widespread group of deposits traceable lithologically from borehole to borehole over great distances. It yields no fossils in the oilfield areas, and for that reason was omitted from foregoing discussions. On the basis of similarity of lithological character and correspondence of position in the column, it is correlated with a notably thicker silt-bearing section to the north and west.

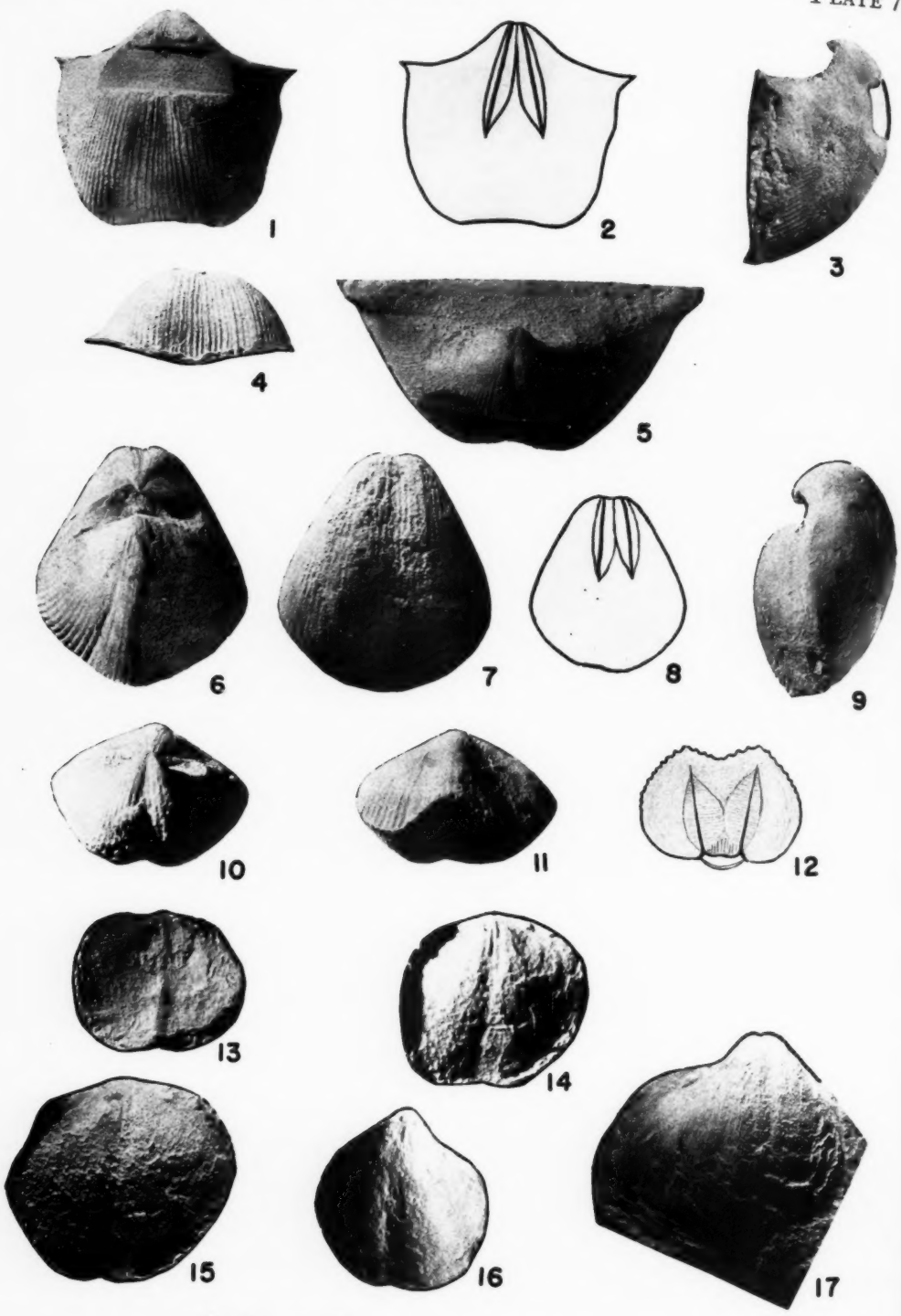
EXPLANATION OF PLATE 76

FIGS. *1–6*—*Spirifer zantedeschii* Crickmay, n. sp. Fig. *1*, Paratype, no. 1, brachial valve, dorsal aspect, ×1.2; *2*, holotype, ventral aspect, ×1.5; *3*, paratype no. 1, posterior aspect, ×1.5. The specimen is distorted; *4*, holotype, posterior aspect, ×1.5; *5*, holotype, impression in rock of exterior, ×10; *6*, paratype no. 2, outlines of section across rostral region, ×3.5. (p. 606)

7–11—*Spirifer eudoxus* Crickmay, n. sp. Fig. *7*, Holotype, dorsal aspect, ×1.8; *8*, paratype no. 1, outlines of section across rostral region, ×4; *9*, holotype, left lateral aspect, ×1.2; *10*, holotype, anterior aspect, ×1.3; *11*, holotype, posterior aspect, ×1.8. (p. 606)



Crickmay, Upper Devonian Brachiopods



Crickmay, Upper Devonian Brachiopods

Where thick, the silt series bears fossils. The lower part of the total silt range appears on Hay River above Alexandra Falls in the red beds with *Gypidula* sp. and the limestones with *Devonoproductus* sp., *Atrypa* sp. and *Cyrtospirifer charitopes* n. sp. The upper part appears in the silty upper portion of the Cheviot formation in the northern Rocky Mountains where it is marked by *Cyrtiopsis mimetes* and *C. prepta*. As has been indicated, the most striking Upper Devonian paleontological hiatus comes in the middle of the silt zone between the ranges of *Cyrtospirifer* and *Cyrtiopsis*.

The dolomite portion of the D_1 zone of the oilfields known as Wabamun formation is unfossiliferous. Its stratigraphic position corresponds to that of Palliser and Boule formations. Its uppermost beds, which are only slightly magnesian, yielded a form of *Cyrtiopsis* comparable with the later species of that genus from a borehole a few miles west of the oilfields. This, together with the silt correlation already presented, limits the Wabamun to a pre-*C. animasensis* post-*C. prepta* position. The very different uppermost, or limestone, portion of D_1 is limited by its fossils to correlation with the upper part of the Banff formation—lower Banff and Exshaw being missing from that section.

DESCRIPTIONS OF SPECIES

Recognition of certain new fossil species is essential to the correlations made in this article.

The type specimens are reposited in the collections of Imperial Oil Limited, Calgary, Alberta.

Class BRACHIOPODA
Superfamily RHYNCHONELLACEA
Family CAMAROTOECHIIDAE
Genus LEIORHYNCHUS Hall

LEIORHYNCHUS CARYA Crickmay, n. sp.
Plate 70, figs. 1–5, 8–11

Description.—Shell of medium size, rotund. Valves very discrepant, brachial being much the more convex. Fold and sulcus somewhat short, plicate. Lateral slopes short, smooth. Anterior commissure strongly episulcate.

Pedicle valve with smooth prominent beak. Sulcus anterior. Plicae three, confined to sulcus, the median one notably largest. Hinge-teeth large, prominent. Dental lamellae much reduced, curved, inclined toward one another, embedded in thick umbonal callus.

Brachial valve strongly convex, with beak deeply immersed within opposing valve. Fold prominent only in anterior region. Development of crural cavity, septum and crura normal, accompanied by thick and extensive growth of callus in umbo. Fold bearing four large, paired plicae and one small median plica.

Exterior of both valves, marked by concentric fila of irregular development.

Dimensions.—Holotype: width, 22 mm.; length, 22 mm.; depth (valves together), 19 mm.

Distinctions.—Resembles only *L. castanea* from which it differs in its greater width, more prominent fold and various aspects of surface conformation.

Occurrence.—Upper 100 feet of Perdrix shale and in succeeding limestone, early

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EXPLANATION OF PLATE 77

FIGS. *1–5—Choristites protistus* Crickmay, n. sp. holotype. Fig. *1*, Ventral aspect, ×1.4; *2*, outline and disposition of lamellae, ventral aspect, ×1.4; *3*, left lateral aspect, ×1.5; *4*, anterior aspect, ×1.3; *5*, posterior aspect, ×2. (p. 607)

6–12—Choristites glennfoxi Crickmay, n. sp. Fig. *6*, Holotype, dorsal aspect, ×1.5; *7*, holotype, ventral aspect, ×1.5; *8*, paratype no. 1, outline and disposition of lamellae, ventral aspect, ×1; *9*, holotype, left lateral aspect, ×1.5; *10*, holotype, posterior aspect, ×1.5; *11*, holotype, anterior aspect, ×1.5; *12*, paratype, no. 1, section across rostral region, ×3. The enormously thickened lamellae coalesce with each other and with the thickened transverse plate. The thin, convex deltidium is in situ. (p. 607)

13–17—Crurithyris youngstownensis Crickmay, n. sp. Fig. *13*, Paratype no. 1, a brachial valve, dorsal aspect, ×6; *14*, paratype no. 2, a brachial valve, dorsal aspect ×5; *15*, paratype no. 2, ×6; *16*, paratype no. 3, a pedicle valve, ventral aspect, ×5; *17*, holotype, a pedicle valve, ventral aspect, ×6. (p. 608)

Upper Devonian (lower Frasnian) on mountain north of Mt. Cheviot, Alberta, Canada. Collected by F. Glenn Fox.

LEIORHYNCHUS BASILICUM Crickmay, n. sp.
Plate 70, figs. 12–21

Description.—Shell, of medium size, subglobular, tumid. Both valves convex; lateral slopes short. Fold and sulcus very short, evident mainly in strongly parasulcate character of anterior commissure. Plicae strictly confined to anterior region. Umbones smooth.

Pedicle valve convex mainly in umbonal region. Hinge-teeth small, variably developed in different specimens. Dental lamellae much reduced, progressing from strongly curved and conjoint at inferior edges to straight and discrete, finally disappearing in thick umbonal callus which extends about 45% of length of valve. Muscle areas deeply impressed. Ovarian impressions strong. Sulcus short, shallow, marked by two (rarely three) short plicae. Lateral slopes short, bearing very short vestigial plicae along anterior margin.

Brachial valve considerably more roundly tumid than pedicle. Sockets shallow. Crural cavity narrow, deep. Median septum strongly developed, long, thick along base, acute topped. Ovarian areas broad, well marked by pits on interior surface. Muscle impressions deep, narrow. Fold short, marked by three (rarely four) short plicae at margin as in pedicle valve.

Exterior smooth except for short anterior plicae, without micro-ornament.

Dimensions.—Holotype: width, 19.5 mm.; length, 19 mm.; depth, 17.5 mm.

Occurrence.—Isolated limestone outcrop on right bank of Mackenzie River, one mile above mouth of Root River, Northwest Territory, Canada.

Superfamily ATRYPACEA
Family ATRYPIDAE
Genus ATRYPA Dalman
ATRYPA COSMETA Crickmay, n. sp.
Plate 71, figs. 1–7

Description.—Shell of less than average size, slightly wider than long, distinctly subquadrate, very moderately biconvex. Anterior commissure sharply and somewhat squarely uniplicate.

Pedicle valve of equal convexity to brachial valve at 28 mm. length, much less convex at full size, becoming concave toward lateral margins, shallowly sulcate at anterior margin. Beak very prominent in young stages, acute, regular in median section, symmetrical, at maturity no longer prominent; foramen very small, round, submesothyrid. Deltidium greatly reduced. Teeth large, prominent. Dental lamellae less reduced than in some species, notably convex toward each other, not much divergent toward floor of valve, less markedly divergent anteriorly than in most species.

Brachial valve much more convex than pedicle, evenly rounded, fold not evident except at anterior commissure. Umbo faintly sulcate; beak well concealed. Sockets large, deep, supported by massive, strongly divergent plates.

Surface of both valves marked by very delicate radial costellae which increase in size with distance from umbo; a very few divide into two, and a few implanted ones appear at 40% of length beyond umbonal region. No other major ornament or marking occurs except at commissure which in some specimens is somewhat lamellose. Entire exterior surface covered with very fine, concentric micro-fila, 13 to 16 in 1 mm.

Dimensions.—Holotype: length, 23 mm.; width, 26 mm.; depth, 9.5 mm.

Occurrence.—Hay River shale, 150 to 250 feet above the base on Hay River, 23 miles upstream from its mouth, Northwest Territory, Canada.

Superfamily SPIRIFERACEA
Family SPIRIFERIDAE
Genus CYRTOSPIRIFER Nalivkin
CYRTOSPIRIFER GLAUCUS Crickmay, n.sp.
Plate 73, figs. 1–9

Description.—Shell strongly transverse, mucronate, moderately and subequally biconvex, multicostellate, with narrow costellate fold and sulcus. Anterior commissure uniplicate. Valves internally crenulate near anterior margin.

Pedicle valve slightly more convex than brachial, with narrow moderately deep sulcus. Sulcus well delimited by strongest pair of costellae between which, at maturity, lie six or seven weaker costellae. Beak moderately incurved, not prominent. Ven-

tral interarea apsacline, short, curved. Delthyrium somewhat broad (about 60°). Teeth short, stout. Dental lamellae about 30% of length of valve, strongly divergent, paralleling furrow between second and third costellae beyond limit of sulcus, greatly thickened with even deposits of callus which line umbonal and apical cavities, producing in the latter what appears to be a short, very deeply immersed, delthyrial plate. A faint median interior ridge present.

Brachial valve with low, narrow fold delimited by strongest pair of furrows, bears at maturity six or seven costellae. Beak low, obscure. Dorsal interarea short. Sockets and plates small. Cardinal process low, rounded, sagitally striate.

Exterior of valves covered to near extremities with numerous radial costellae. On fold and in sulcus, costellae increase by implantation in the median zone. Micro-ornament almost lacking, consisting of very fine, almost invisible concentric fila, and in furrows, radial striae, about 35 in 1 mm., so faint as to be almost invisible.

Dimensions.—Holotype (reconstructed): width, 50 mm.; length, 13 mm.; depth (pedicle valve), 4 mm.

Paratype No. 1: width, 76 mm.

Paratype No. 2: length, 16 mm.; depth (pedicle valve), 6 mm.

Occurrence.—Hay River shale, 110 feet above base, on Hay River, 14 miles from its mouth, Northwest Territory, Canada. The species is exceedingly rare, about one specimen found to 200 of the associated species, *Eleutherokomma reidfordi.*

Cyrtospirifer thalattodoxa
Crickmay, n. sp.
Plate 72, figs. 1–8

Description.—Shell large, about equally biconvex, of considerable length and depth; lateral margins short, rounded; extremities acute; shell-outline changing with growth from semicircular to wing-shaped; extremities approximately right-angled up to 15 or 20 mm. width, becoming strongly though coarsely mucronate with maturity. Anterior commissure strongly and roundly uniplicate.

Pedicle valve with sulcus strongly marked from umbo. Beak prominent, incurved. Ridges from beak to extremities thick, obtuse, with convex surfaces immediately to anterior. Ventral interarea apsacline, short, curved, divided into discrepantly marked sub-areas; inner sub-area with sagittal striation broad. Apical and umbonal cavities lined with thin to medium deposit of callus. Delthyrium about 50°, with thick, deeply submerged transverse plate of average length. Teeth stout, prominent. Dental lamellae strong, strongly divergent ventrally, parallel to second costa outside sulcus, 30% of length of valve, tending slightly toward parallelism anteriorly in some specimens.

Brachial valve with fold evident from umbo but not prominent until within 33% of length from anterior margin. Beak prominent, incurved. Dorsal interarea short, apsacline. Sockets deep. Socket plates stout above, convergent and delicate basally. Cardinal process broad, low, sagitally finely striate, buttressed to valve by considerable callus.

Exterior of both valves marked by numerous (total about 69), low, round to flat, continuous, simple costae which show faintly on interior. Fold and sulcus marked by 10 to 12 slightly smaller costae which increase by branching according to a definite and unvarying pattern. Lateral slopes bear simple costae which are strongest next to fold and sulcus, decrease considerably in size near extremities where they become irregularly wavy. Micro-ornament consists of numerous closely approximate, concentric microfila, about 11 in 1 mm.; strongest within furrows between costae. Here and there appear exceedingly fine, weak, irregular, radial striae. Micro-pustules distributed over entire exterior surface on costae, some arising at intersections of striae and fila, many ranged in short series parallel to growth-lines.

Dimensions.—Holotype: width, 50 mm.; length, 31 mm.; depth (valves together), 22 mm.; length of brachial valve, 27 mm.

Distinctions.—Separable from *C. whitneyi* and other Iowa species by its large size, short interarea, considerable length in proportion to width.

Remarks.—It is to be noted that young specimens are very different from old ones in outlines and dimension ratios.

Occurrence.—Hay River shale 300 feet above base, on Hay River 23 miles from mouth, Northwest Territory, Canada.

CYRTOSPIRIFER CHARITOPES
Crickmay, n. sp.
Plate 71, figs. 14–19

Description.—Shell of average size, subequally biconvex, of considerable width. Outline semi-circular up to a width of 15 mm.; developing acutely mucronate extremities at width of 20 to 22 mm. Anterior commissure gently uniplicate.

Pedicle valve with narrow, shallow sulcus marked from umbo. Beak prominent, incurved, slightly twisted in most specimens. Ridges from beak to extremities thin, acute with concave surfaces immediately to anterior giving the extremities a twisted appearance. Ventral interarea apsacline, of medium length, curved, divided into discrepantly marked sub-areas; inner subarea with sagittal striation broad. Delthyrium about 53°, with short, deeply submerged, transverse plate. Teeth strong, but not coarse. Dental lamellae strong, somewhat divergent ventrally, parallel to second costa outside sulcus, 35% or more of length of valve.

Brachial valve with fold evident from umbo, well rounded throughout. Beak prominent, strongly incurved. Dorsal interarea short, twisted, apsacline. Sockets deep, narrow. Socket-plates stout above, convergent and delicate basally. Cardinal process broad, low, sagitally finely striate, buttressed to valve by delicate callus.

Exterior of both valves marked by numerous (total about 71), fine, round-topped, continuous, costae showing faintly on interior. Fold and sulcus marked by 10 to 12 costae which increase by branching according to a definite and unvarying pattern. Lateral slopes bear simple costae which are strongest next to fold and sulcus, decreasing regularly in size toward extremities. Micro-ornament consists of regular concentric micro-fila, 12 to 14 in 1 mm., strongest within furrows. Micro-pustules thick over exterior on costae, many ranged in short series parallel to growth lines.

Dimensions.—Holotype: width, 38.5 mm.; length, 23.5 mm.; depth (two valves), 16 mm.; length of brachial valve, 19 mm.

Distinctions.—The delicate ornament, twisted ventral beak, and high acute beak-ridges distinguish this species. Most nearly resembles *C. whitneyi;* differs in having much less depth of valves, much less labial extension of sulcus.

Occurrence.—Grumbler formation, basal red beds, in the first 20 feet immediately below Vermilion Chutes, Alberta; also on Hay River, 38 miles from mouth, Northwest Territory, Canada.

CYRTOSPIRIFER ALEXANDRAE
Crickmay, n. sp.
Plate 71, figs. 8–13

Description.—Shell smaller than average, equally and strongly biconvex, deep and narrow in proportion to length; lateral margins rounded; extremities developing from round to square to acute in largest specimens. Anterior commissure strongly and roundly uniplicate.

Pedicle valve with sulcus strongly marked from umbo. Beak prominent, incurved. Ventral interarea apsacline, long, curved. Delthyrium about 50°, with somewhat short, submerged transverse plate. Teeth strong, prominent. Dental lamellae strong, deeply embedded in callus which fills apical and umbonal cavities, diverging somewhat toward floor of valve, parallel to second costa outside sulcus, 30% of length of valve.

Brachial valve with fold prominent from umbo. Beak prominent, incurved. Dorsal interarea longer than average, apsacline to orthocline. Sockets deep. Socket-plates larger than average. Cardinal process small, regular, symmetrical, sagitally striate.

Exterior of both valves marked by numerous, fine, round-topped costae showing faintly on interior. Fold and sulcus bear 11 to 12 costae increasing by branching according to a definite and unvarying pattern. Lateral slopes bear costae decreasing slightly in size as extremities are approached.

Micro-ornament consists of closely approximate, concentric micro-fila, strongest within furrows. Costae bear scattered micro-pustules.

Dimensions.—Holotype: width, 27 mm.;

length, 22 mm.; depth (valves together), 17.5 mm.; length of brachial valve, 19 mm. Width of largest known specimen, 30 mm.

Distinctions.—The small size, symmetry, regular conformation, great length and depth in proportion to width are distinctive.

Occurrence.—Base of Alexandra Falls limestone (formerly "Hay River Limestone") on Hay River, 31 miles from mouth, Northwest Territory, Canada.

Genus TENTICOSPIRIFER Tien
TENTICOSPIRIFER KELETICUS
Crickmay, n. sp.
Plate 73, figs. 10–19

Description.—Shell small, unequally biconvex, multicostellate, of subcircular outline, notably deep; cardinal extremities well rounded; anterior commissure gently and roundly uniplicate.

Pedicle valve with narrow shallow sulcus beginning at umbo. Beak prominent, erect. Ventral interarea long, apsacline, nearly catacline in some specimens, slightly curved. Delthyrium 35° to 40°, with long, shallowly submerged, transverse plate of considerable thickness. Deltidium not observed. Teeth stout, short. Dental lamellae thin, long (40% of length of valve), diverging gently both basally and toward anterior. Apical and umbonal cavities lined with thick callus not extending anteriorly more than 10% of length of valves.

Brachial valve with very inconspicuous fold. Beak somewhat prominent. Dorsal interarea orthocline. Sockets shallow. Socket plates strong. Cardinal process small, sagittally striate, buttressed to valve by considerable callus of shape of two-pronged fork.

Exterior of both valves marked by fine, delicate costellae; on fold and sulcus branching according to a definite pattern, 12; on lateral slopes, simple, 19. Micro-ornament of fine, undulant, radial micro-striae, and concentric micro-fila.

Dimensions.—Holotype: width, 19 mm.; length, 19 mm.; depth (valves together), 15 mm.; length of brachial valve, 15 mm.

Distinctions.—The fine ornament and peculiar shell conformation are distinctive.

Occurrence.—"*Leiorhynchus* Limestone," left bank of Mackenzie River, eight miles above mouth of North Nahanni River, Northwest Territory, Canada.

Genus CYRTIOPSIS Grabau
CYRTIOPSIS NAHANNIENSIS
Crickmay, n. sp.
Plate 72, figs. 9–15

Description.—Shell of average size, unequally biconvex, multi-costellate, short, deep; lateral margins rounded, cardinal extremities, acute; anterior commissure strongly and angularly uniplicate.

Pedicle valve with deep, narrow-bottomed sulcus from umbo. Beak prominent, erect, in some specimens twisted. Ventral interarea long, apsacline, slightly curved. Delthyrium varying from 35° to 48°, with shallowly submerged, thick transverse plate of considerable length (35% of length of delthyrium). Deltidium not observed. Teeth stout, short. Dental lamellae thin, long (45 to 50% of length of valve), duplex in structure thereby splitting mesially in many specimens, subparallel, diverging very slightly toward floor of valve where they lie within sulcus, curving somewhat toward one another at anterior ends. Apical and umbonal cavities lined by thin callus.

Brachial valve with sharp-ridged fold evident from umbo, but not prominent short of anterior margin. Beak low, incurved. Dorsal interarea greatly reduced. Sockets shallow. Socket-plates strong. Cardinal process small, low, sagitally striate, buttressed to valve by small callus.

Exterior of both valves marked by numerous round-topped costellae; costellae on fold and sulcus branch according to definite pattern, some smaller than average, 27 to 22 at full growth; on lateral slopes, simple, 15 to 17 at full growth. Micro-ornament of weak, continuous, radial micro-striae and strong concentric micro-fila. Micro-striae frequently increase and decrease in height periodically along their courses, giving an undulant appearance. No trace of micro-pustules.

Dimensions.—Holotype: width, 25 mm.; length, 19 mm.; depth (valves together), 17 mm.; length of brachial valve, 15 mm. Paratype No. 1: width, 27 mm.; length, 22 mm.; depth (valves together), 21 mm.; length of brachial valve, 15.5 mm.

Distinctions.—The angular fold and sulcus distinguish *C. nahanniensis* from all but *C. mimetes* and it can be separated from this by its fine ribbing.

Occurrence.—In the so-called "*Leiorhynchus* Limestone" of the late Upper Devonian, left bank of Mackenzie River, eight miles above mouth of North Nahanni River, Northwest Territory, Canada.

CYRTIOPSIS MIMETES Crickmay, n. sp.
Plate 75, figs. 1–8

Description.—Shell of average size, subequally biconvex, multi-costellate, short, deep; lateral margins rounded; extremities somewhat square. Anterior commissure angularly uniplicate.

Pedicle valve with deep, narrow-bottomed sulcus beginning on umbo. Beak prominent, incurved. Ventral inter-area of medium length, apsacline, curved. Delthyrium about 50°, with thick, long, shallowly submerged transverse plate. Deltidium thin, strongly arched. Teeth thin, short. Dental lamellae in very young shells thin and divergent; in mature shells, thick, very little divergent, curved toward one another at anterior ends, of duplex structure thereby splitting mesially in many specimens. Apical and umbonal cavities filled with callus.

Brachial valve with flat-topped, low fold evident from umbo. Beak not prominent. Dorsal interarea reduced. Sockets small, shallow. Socket-plates inconspicuous. Cardinal process small, sagittally striate, buttressed to valve by short thin median septum.

Exterior of both valves marked by numerous costellae showing fairly strongly on interior. Fold and sulcus marked by narrow mesial smooth zone with three to four costellae on each side arising according to a definite pattern. Lateral slopes bear 12 costellae.

Micro-ornament of strong continuous radial micro-striae, and weaker concentric micro-fila. Micro-striae frequently increase and decrease in height periodically along their courses giving an undulant appearance. No trace of micro-pustules.

Dimensions.—Holotype: width, 24 mm.; length, 20 mm.; depth (valve together), 16 mm.; length of brachial valve, 15 mm.

Distinctions.—Smooth mesial zones on fold and sulcus distinguish this from all but *C. prepta* which has a considerably longer and flatter interarea.

Occurrence.—In Cheviot formation, 150-190 feet below top, late Upper Devonian, Deception Creek, a tributary of the Rocky River system, approximately 30 miles due east of Jasper, Alberta.

CYRTIOPSIS PREPTA Crickmay, n. sp.
Plate 75, figs. 9–16

Description.—Shell somewhat over average size, unequally biconvex, multicostate; lateral margins and cardinal extremities rounded; anterior commissure uniplicate.

Pedicle valve with deep narrow-bottomed sulcus beginning on umbo. Beak prominent, high, very slightly incurved. Ventral interarea long, apsacline, very slightly curved with sagittally striate inner subarea. Delthyrium about 40° with shallowly submerged transverse plate of considerable length (40 to 45% of length of delthyrium). Deltidium not observed. Teeth thin, small. Dental lamellae thin, long (45 to 50% of length of valve), diverging slightly, parallel to edge of sulcus, converging at anterior ends and coming well within sulcus. Apical and umbonal cavities filled with callus.

Brachial valve with low, rounded fold evident from umbo, never prominent. Beak prominent, incurved. Dorsal interarea narrowed, somewhat more than average length. Sockets shallow. Socket-plates inconspicuous. Cardinal process small, sagittally striate, buttressed to valve by ridgelike callus.

Exterior of both valves marked by small radial costae. A narrow, median, smooth zone separates costae of fold and sulcus into two paired groups of three or four each. About 15 to 18 costae on lateral slope. Micro-ornament of strong radial microstriae on costae and in furrows, and faint concentric micro-fila.

Dimensions.—Holotype: width, 27 mm.; length, 26 mm.; depth (valves together), 18 mm.; length of brachial valve, 18 mm.

Distinctions.—The median smooth zone of fold and sulcus distinguishes this from all but *C. mimetes* and from this it can be separated by its long interarea.

Occurrence.—Cheviot formation, 120 feet below the top, late Upper Devonian, Deception Creek, a tributary of the Rocky River system, approximately 30 miles due east of Jasper, Alberta.

CYRTIOPSIS NORMANDVILLANA
Crickmay, n. sp.
Plate 74, figs. 1–8

Description.—Shell of somewhat less than average size; valves very unequal, of very discrepant conformation; lateral margins rounded; extremities nearly right-angled; anterior commissure parasulcate.

Pedicle valve with large sulcus beginning on umbo. Beak prominent, erect. Ventral interarea outstandingly long, almost catacline, nearly flat. Delthyrium very narrow, about 28°, with long, thick transverse plate becoming somewhat submerged with growth. Deltidium not observed. Teeth stout, short. Dental lamellae very long (55% of length of shell), diverging little basally, lying entirely within sulcus, parallel at their anterior ends. Apical region with very little callus.

Brachial valve with low, rounded fold beginning on umbo. Beak small, incurved. Dorsal interarea orthocline to apsacline. Sockets large. Socket-plates stout. Cardinal process large, sagittally striate, buttressed to valve by short, stout median septum.

Exterior of both valves marked by numerous, fine, strong costellae showing prominently on interior. Fold and sulcus marked by 13 to 14 costellae which arise by branching. Lateral slopes bear about 25 simple costellae. Micro-ornament of strong, continuous radial striae, showing faintly on interior, three to five on each costella with narrow zone without striae in bottom of each furrow. All crossed by much finer concentric micro-fila, about 20 to 1 mm.

Dimensions.—Holotype: width, 22 mm.; length, 19 mm.; depth (valves together), 17 mm.; length of brachial valve, 15 mm.

Distinctions.—Distinguished by long palintrope and acute ornament. It is narrower than *C. animasensis* Girty.

Occurrence.—So-called D1 zone, late Upper Devonian, in Imperial Normandville No. 1 borehole, Section 2, Township 79, Range 22, west of 5th Meridian, Alberta, Canada, at 6032 feet.

CYRTIOPSIS HIRAETHLYNAE
Crickmay, n. sp.
Plate 74, figs. 9–14

Description.—Shell of average size, subequally biconvex, multi-costellate, wide; cardinal extremities acute; anterior commissure uniplicate.

Pedicle valve with broad, shallow sulcus evident from umbo but ill-defined. Beak prominent, slightly incurved. Ventral interarea apsacline, of medium length, slightly curved below beak, flat toward cardinal margin. Delthyrium about 45°, with a very long (50%), shallowly submerged transverse plate. Deltidium thin, strongly arched, discrete from underlying transverse plate. Teeth large. Dental lamellae long (45%), thin, straight, diverging very slightly toward their bases and in anterior direction. Apical and umbonal cavities filled with thick extensive callus backing transverse plate for its entire length and investing lamellae for half their length.

Brachial valve with low, rounded fold evident from umbo but ill-defined. Beak low, inconspicuous. Dorsal interarea reduced. Sockets large. Socket-plates stout, deep. Cardinal process low, sagittally striate, buttressed to valve by short, delicate median septum.

Exterior of both valves delicately costellate. Fold and sulcus bear 14 costellae which arise by branching. Lateral slopes marked by about 25 simple costellae.

Micro-ornament of very fine radial microstriae, about 7 or 8 on top and sides of each costella, showing frequently repeated variations of strength producing characteristic undulant appearance. Traces of faint, irregular, concentric micro-fila. No micropustules.

Dimensions.—Holotype: width, 32 mm.; length (brachial valve), 18 mm.; depth (brachial valve), 5 mm. Paratype (pedicle valve): width: 23; length, 16.5; depth, 7.

Distinction.—The great width at the cardinal margin, and the ill-defined and inconspicuous fold and sulcus are distinctive. From *C. gallatinensis* Haynes, the species differs in its lesser depth; from *C. monticola* Haynes, in its greater width. Some of the illustrated specimens from Three Forks, Montana, may well be refer

able to this species. A definite clarification of the distinctions among the Three Forks forms of *Cyrtiopsis* must await further study of the types.

Occurrence.—Three Forks shale, late Upper Devonian, in Imperial Youngstown No. 1 borehole, Section 3, Township 30, Range 9, west of the 4th Meridian, Alberta, Canada, at 3438 feet.

Genus SPIRIFER Sowerby

SPIRIFER ZANTEDESCHII Crickmay, n. sp.

Plate 76, figs. 1–6

Description.—Shell of average size, wide lacking perfect symmetry and conformity with the normal growth curves, multicostate; lateral margins irregularly rounded; cardinal extremities terminating in short mucrones; anterior commissure broadly uniplicate.

Pedicle valve with broad, deep sulcus having indefinite limits. Beak prominent, somewhat incurved; beak-ridges not prominent. Ventral interarea of average length, apsacline, slightly curved. Delthyrium of medium width (60°), with a long, deeply submerged transverse plate. Deltidium not observed. Teeth large. Dental lamellae strong, widely diverging toward their bases and toward anterior, thickened with callus for much of their length, thin and acute at their anterior edges. Apical and umbonal cavities filled with callus on which lies a strong, blunt median ridge between the lamellae somewhat resembling the median septum of some genera.

Brachial valve with broad, rounded fold, well-defined by furrows in umbonal region, of indistinct lateral limits anteriorly. Beak low, incurved. Dorsal interarea orthocline to apsacline, somewhat reduced. Sockets large, shallow. Socket-plates strong. Cardinal process small, low, flat.

Exterior of both valves marked by numerous, obtuse costae, about 14 in fold and sulcus at full growth, about 20 to 24 on lateral slopes. Micro-ornament of fine, strong, concentric fila, about three to six in 1 mm., and very faint, radial microstriae, about 12 to 14 in 1 mm.

Dimesions.—Holotype: width, 40 mm.; length, 24 mm.; depth (ventral valve), 9 mm. Paratype: width, 38 mm.; length (dorsal valve), 21 mm.; depth (dorsal valve), 8 mm.

Distinctions.—Differs from *Spirifer* species in general by its strong, concentric micro-ornament. Separable from related species with similar micro-ornament by its lack of perfect symmetry, great width of fold and sinus, and spacing of fila. Resembles *S. imbres* Hall and *S. incertus* Hall.

Occurrence.—Upper part of D_1 zone, Mississippian, (formerly referred to Devonian), in Imperial Ireton No. 1 borehole, Section 10, Township 49, Range 26, west of the 4th Meridian, Alberta, Canada, at 4790 feet.

SPIRIFER EUDOXUS Crickmay, n. sp.

Plate 76, figs. 7–11

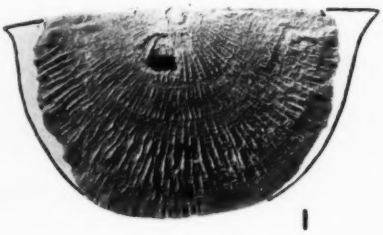
Description.—Shell of average size, multicostate; lateral margins somewhat straight; cardinal extremities terminating in short, acute points; anterior commissure gently uniplicate.

Pedicle valve with narrow, ill-defined sulcus. Beak prominent, regular, symmetrical, incurved; beak-ridges strong, acute. Ventral interarea of average length, apsacline, curved. Delthyrium about 50°; transverse plate strong; deltidium not observed. Teeth strong, prominent but not coarse. Dental lamellae strong, long, straight, gently diverging. Apical and umbonal cavities filled with callus.

EXPLANATION OF PLATE 78

FIGS. *1–6*—*Nervostrophia vestita* Crickmay, n. sp. Fig. *1*, Holotype, ventral aspect, ×1.4, outline in part restored; *2*, paratype no. 1, postero-dorsal aspect of apical region, ×6; *3*, holotype, central region of disk, ventral aspect, ×6; *4–6*, paratype no. 2, oblique sections of umbo of pedicle valve; *4*, ×7; *5*, ×5; *6*, ×4. (p. 608)

7–10—*Chonopectus horaeus* Crickmay, n. sp. Fig. 7, Holotype, dorsal aspect, ×7.5; *8*, paratype no. 1, ventral aspect, ×8; *9*, paratype no. 2, an incomplete specimen, ventral aspect, ×10; *10*, paratype no. 2, portion of disk, lower right part has shell intact, upper left part has shell removed, ×30. (p. 609)



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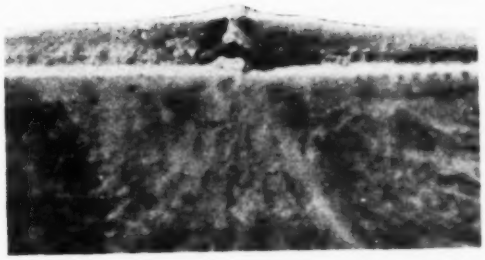

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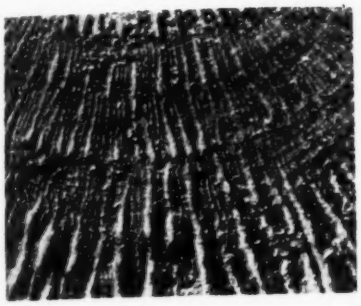

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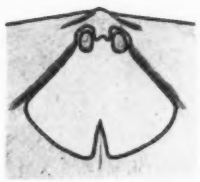

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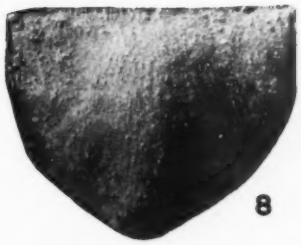

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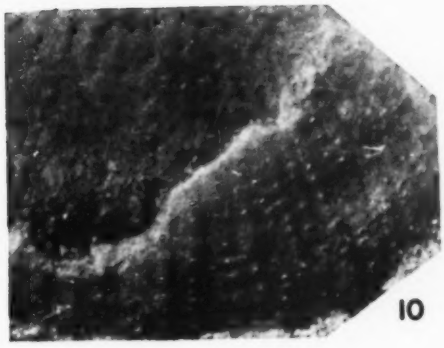
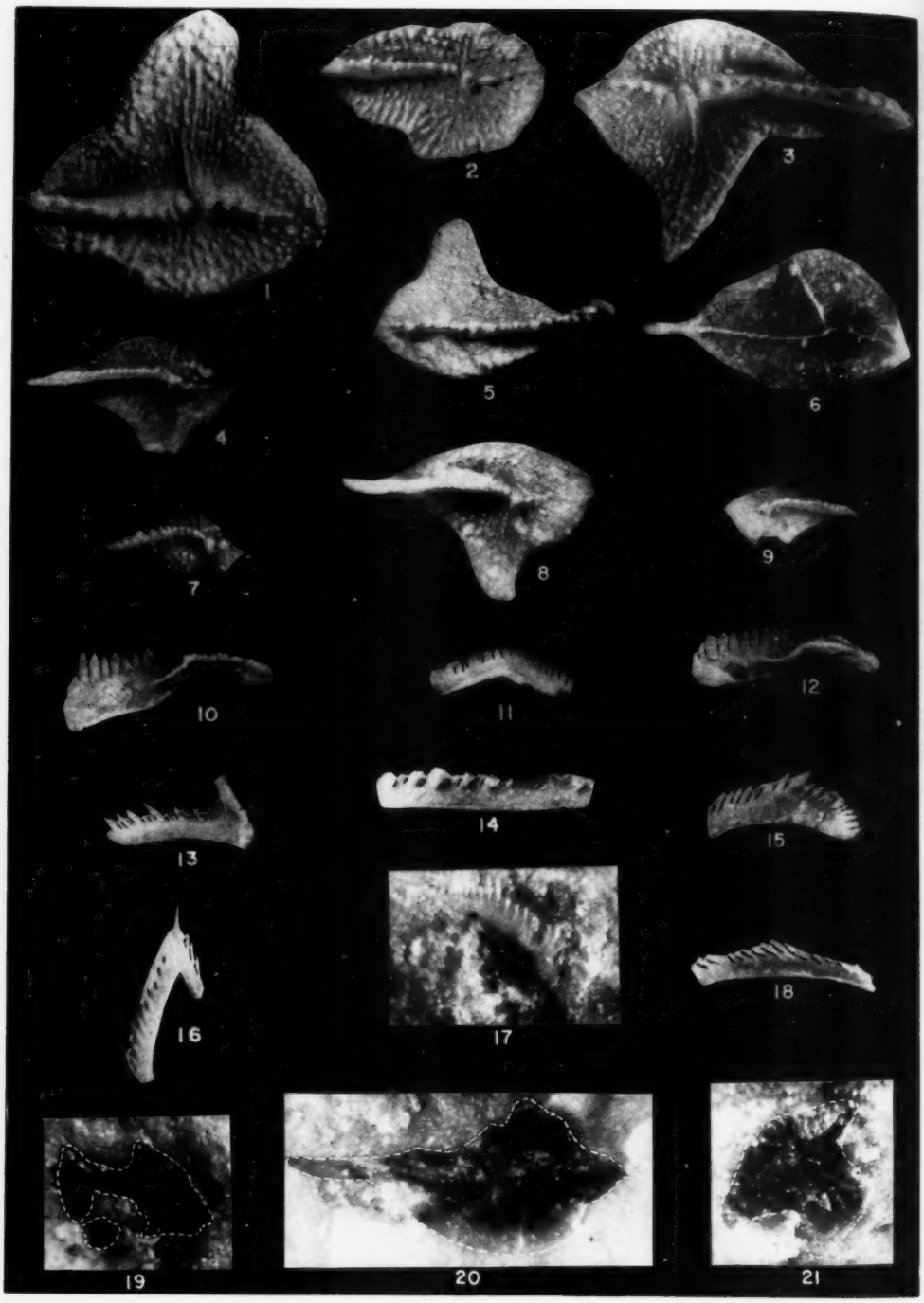


10

Crickmay, Upper Devonian Brachiopods



Graves, Devonian Conodonts from Texas

Brachial valve with low fold. Beak low, incurved. Dorsal interarea reduced. Sockets deep. Socket-plates strong. Cardinal process small, flat.

Exterior of both valves marked by numerous (26 on each half of valve), fine, strong costae. Micro-ornament of fine, irregular, concentric lines.

Dimensions.—Holotype: width, 43 mm.; length, 31 mm.; depth (pedicle valve), 15 mm.

Distinctions.—Characterized by symmetrical, regular conformation; fine, strong costation; and fine, concrescent micro-ornament. Resembles *S. shepardi* Weller but is longer, has deeper pedicle valve, and longer interarea.

Occurrence.—Upper part of D_1 zone, Mississippian (formerly referred to Devonian), in Imperial Ireton No. 1 borehole, Section 10, Township 49, Range 26, west of the 4th Meridian; Alberta, Canada, at 4790 feet.

Genus CHORISTITES Fischer

CHORISTITES PROTISTUS Crickmay, n. sp.
Plate 77, figs. 1–5

Description.—Shell somewhat small, wider than average of genus, subpentagonal in outline, multi-costellate; cardinal extremities acute; anterior commissure gently uniplicate; greatest width at cardinal margin.

Pedicle valve with shallow sulcus beginning on umbo. Beak prominent, incurved. Ventral interarea long, apsacline, slightly curved. Delthyrium 65°. Neither transverse plate nor deltidium observed. Teeth strong, prominent. Dental lamellae long, subparallel, greatly thickened by regular deposit of shell material quite distinct from umbonal callus. Apical and umbonal cavities much reduced by thickening of lamellae, filled with extensive callus.

Exterior of valve marked by numerous costellae which increase by branching in sulcus, but appear simple on lateral slopes. Micro-ornament of very fine, concentric micro-fila which appear strong only in furrows.

Dimensions.—Holotype: width, 24 mm.; length, 22.5 mm.; depth, (pedicle valve), 9 mm.

Distinctions.—Greatest width at the cardinal margin marks this as a distinct and early species of the genus.

Occurrence.—Limestone directly below Exshaw shale in Imperial Normandville No. 1 well, Section 11, Township 79, Range 22, West of 5th Meridian between 5502 and 5512 feet, with *Crurithyris* sp.; *Leioproductus* sp., etc., bi-valves among which are disarticulated.

CHORISTITES GLENNFOXI Crickmay, n. sp.
Plate 77, figs. 6–12

Description.—Shell small, narrow, long, multi-costellate. Hinge-line becoming

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EXPLANATION OF PLATE 79

Siliceous shale fauna. All figures ×30.

FIGS. *1, 3—Palmatolepis perlobata* Ulrich and Bassler. Plastic cast. University of Texas Bureau of Economic Geology Nos. 31978, 31980. (p. 612)

2, 4, 5, 8—Palmatolepis subperlobata Branson and Mehl. Plastic cast. University of Texas Bureau of Economic Geology Nos. 31979, 31981, 31982, 31985. (p. 612)

6—Palmatolepis cf. *P. delicatula* Branson and Mehl. Plastic cast. University of Texas Bureau of Economic Geology No. 31983. (p. 612)

7, 9, 10, 12, 19–21—Palmatolepis sp. Nos. *7, 9, 10, 12* are plastic casts. University of Texas Bureau of Economic Geology Nos. 31984, 31986, 31987, 31989, 31996–31998. (p. 612)

11—Spathognathodus? sp. Plastic cast. University of Texas Bureau of Economic Geology No. 31988. (p 612)

13—Ligonodina? sp. Plastic cast. University of Texas Bureau of Economic Geology No. 31990. (p. 612)

14—Hindeodella? sp. Plastic cast. University of Texas Bureau of Economic Geology No. 31991. (p. 612)

15, 17—Ozarkodina sp. No. *15* is a plastic cast. University of Texas Bureau of Economic Geology Nos. 31992, 31994. (p. 612)

16, 18—Synprioniodina sp. Plastic casts. University of Texas Bureau of Economic Geology Nos. 31993, 31995. (p. 612)

shorter with growth; at maturity cardinal extremities quite inconspicuous and outline subtriangular. Greatest width considerably anterior to center of disk. Anterior commissure gently uniplicate.

Pedicle valve long, very strongly umbonate, with strong sulcus beginning on umbo. Beak strongly incurved. Ventral interarea nearly orthocline, curved. Delthyrium about 60°, completely closed by very slightly arched deltidium. Transverse plate long, shallowly submerged. Teeth strong, prominent. Dental lamellae long, straight, subparallel, greatly thickened, coalescent in the apical region. Apical and umbonal cavities filled with very extensive callus extending half length of valve but leaving tube-like vaults in umbonal cavities.

Brachial valve subcircular, with rounded fold beginning on umbo. Beak low, incurved. Dorsal interarea greatly reduced. Sockets deep. Socket-plates strong. Cardinal process broad, flat, sagittally striate. Spiralia with many approximate coils, extending strongly in posterolateral direction.

Exterior of both valves marked by fine, radial costellae.

Dimensions.—Holotype: width, 20 mm.; depth (valves together), 14 mm.; length of brachial valve, 16 mm.

Distinctions.—Outline and conformation are distinctive.

Occurrence.—Upper 50 feet of Palliser formation, at first peak southeast of railroad, in Nikanassin Range, near Cadomin, Alberta. Collected by F. Glenn Fox, geologist, formerly with Imperial Oil Limited.

Family AMBOCOELIIDAE
Genus CRURITHYRIS George
CRURITHYRIS YOUNGSTOWNENSIS
Crickmay, n. sp.
Plate 77, figs. 13–17

Description.—Shell very small, very unequally biconvex, with rounded outline and very short hinge (50% of width); anterior commissure minutely sulcate.

Pedicle valve very strongly convex, with extremely narrow furrowlike sulcus extending from umbo to anterior region but failing to reach anterior margin. Beak prominent, thick, incurved. Ventral interarea very narrow, long, nearly orthocline. Delthyrium of medium width, 55°. Teeth delicate, thin, short. Dental lamellae greatly reduced, widely divergent, embedded in umbonal callus which is concave in each umbonal cavity and projects anteriorly very slightly in median region.

Brachial valve gently convex, with extremely narrow, furrowlike sulcus originating immediately anterior to umbo and attaining anterior margin. Beak very small, inconspicuous. Sockets of considerable size. Socket-plates strong. Cardinal process subpyramidal. Crural lamellae stout, short, tapering to thin edges, diverging slightly anteriorly.

Exterior of both valves almost smooth, marked only by very faint, concentric lines visible only under magnification. Interior marked by weak, irregular, radial lines.

Dimensions.—Holotype: width, 8 mm.; length, 7 mm.; depth, (pedicle valve), 3.5 mm.

Paratype: (brachial valve): width, 7 mm.; length, 4 mm.; depth, 1 mm.

Distinctions.—The short hinge and massive umbo distinguish this from other well-known species.

Occurrence.—Three Forks formation in Imperial Youngstown No. 1 borehole, Section 3, Township 30, Range 9, west of the 4th Meridian; Alberta, Canada, at 3457 feet.

Superfamily STROPHOMENACEA
Family STROPHEODONTIDAE
Genus NERVOSTROPHIA Caster
NERVOSTROPHIA VESTITA Crickmay, n. sp.
Plate 78, figs. 1–6

Description.—Shell very thin, of average size, roughly semicircular with acute cardinal extremities; hinge-line denticulate for 75% of its length.

Pedicle valve very slightly convex. Beak exceedingly small, symmetrical. Ventral interarea short, sagittally striate in accordance with the distribution of hinge-denticles, apsacline. Delthyrium small. Deltidium short, highly convex, rough, roundly concave toward opposing chilidium. Internally paired, diverging myophore-ridges strong, rugose, prominent. A short median septum (20% of length of valve) divides as it approaches the beak, producing a narrow, median, apical cavity terminated in the apical direction by a stout, bilobed delthyrial process. No trace of an apical foramen.

Brachial valve very slightly concave. Beak quite inconspicuous. Dorsal interarea very short, between hypercline and anacline, sagittally striate to correspond with ventral interarea. Notothyrium filled with rough, convex chilidium, which is concave toward opposing deltidium, forming between them a functional, circular, intervalvular foramen. Cardinal process prominent, bilobed; in articulated specimens lobes of cardinal process embrace delthyrial process, extending deeply into paired umbonal cavities of pedicle valve. A delicate brachiophore arises laterally from base of cardinal process. Paired, diverging myophore-ridges strong, rugose, prominent, closely accordant with those of pedicle valve. Median septum strong, about 25% of length of valve.

Interiors of both valves thickly spotted with papilliform pseudo-punctae. Exterior marked by radial costellae, separated by spaces bearing 2 to 4 radial threads. Costellae of irregular direction, variable distribution, and discontinuous, waxing and waning in strength. Concentric micro-fila cover entire surface. Ornament notably weaker on brachial valve.

Dimensions.—Holotype: width, 41 mm.; length, 22 mm.; depth (valves together), 2 mm.

Remarks.—Toward the margin of the interior occur adventitious lamellae, which to judge by their irregularity, appear to have been built to repair injuries.

Distinctions.—The proportions distinguish this from other species.

Occurrence.—Hay River shale, on Hay River 22 miles from mouth, Northwest Territory, Canada, 200 feet above base of formation.

Family CHONETIDAE
Genus CHONOPECTUS Hall and Clarke
CHONOPECTUS HORAEUS Crickmay, n. sp.
Plate 78, figs. 7–10

Description.—Shell very small, semicircular with right-angled cardinal extremities, strongly concavo-convex.

Pedicle valve strongly convex. Posterior margin with a few large, rarely preserved spines. In type specimen one long spine half as long as width of shell stands at right angles to posterior margin near each extremity. Ventral interarea short. Beak small. Internal structures obscure.

Interiors of both valves bear minute pseudo-punctae. Exterior with radial striae and concentric fila which combine to produce a fine checkered pattern of minute punctae.

Dimensions.—Holotype: width, 5.5 mm.; length, 5 mm.; depth, 2 mm.

Distinctions.—The small size of shell and the small number and great length of posterior spines make this species distinctive.

Occurrence.—So-called D1 zone, late Upper Devonian, in Imperial Normandville No. 1 borehole, Section 11, Township 79, Range 22, west of the 5th Meridian; Alberta, Canada at 6032 feet.

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JOURNAL OF PALEONTOLOGY, VOL. 26, NO. 4, PP. 610–612, PLS. 79–81, 1 TEXT FIG., JULY 1952

DEVONIAN CONODONTS FROM THE CABALLOS NOVACULITE[1]

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ABSTRACT—Conodonts were collected from siliceous shale and limestone of the Caballos novaculite at two localities in the Marathon Basin, Brewster County, Texas. On the basis of the occurrence of the genera *Icriodus* and *Palmatolepis* the upper part of the Caballos novaculite is interpreted as Devonian in age. The Caballos conodont faunas are compared with similar faunas in the Mid-Continent region and in the West Texas-New Mexico subsurface. This is some of the first convincing fossil evidence on the age of the Caballos novaculite.

INTRODUCTION

CONODONTS were collected from the Caballos novaculite at two localities in the Marathon Basin, Brewster County, Texas. One collection was obtained from siliceous shales in the upper part of the formation on East Bourland Mountain; the other collection was obtained from a limestone lens in the upper part of the formation in the Payne Hills (fig. 1). These collections were made during the summers of 1947 and 1948 in connection with field studies for the University of Texas, Bureau of Economic Geology.

ACKNOWLEDGMENTS

Acknowledgment is made for the encouragement and advisory assistance rendered by S. S. Goldich during the course of two field seasons. Thanks are due to R. B. Haynie and R. L. Manly for assistance with the field work; to S. P. Ellison, Jr., for aid in identifying the conodonts and for critically reading the manuscript.

[1] Published with permission of the Director, Bureau of Economic Geology, The University of Texas.

DISCUSSION

Conodonts were first reported from the Caballos novaculite by King (1937, pp. 49, 52) who did not, however, identify or describe the specimens. Heretofore, no fossils other than Radiolaria (Baker and Bowman, 1917, p. 100–101, pl. 2; Henbest, 1936; Aberdeen, 1940) have been illustrated or described from the Caballos novaculite. Fossil wood has been reported from the formation by Leo Hendricks (personal communication).

The two occurrences of conodonts reported here are from the upper part of the Caballos novaculite. Those in the upper

EXPLANATION OF PLATE 80

Limestone fauna. All figures ×30.

FIGS. *1, 4, 10—Oistodus inclinatus* Branson and Mehl. University of Texas Bureau of Economic Geology Nos. 31999, 32002, 32008. (p. 612)

2, 3, 6—Palmatolepis sp. University of Texas Bureau of Economic Geology Nos. 32000, 32001, 32004. (p. 612)

5, 17—Ligonodina? sp. University of Texas Bureau of Economic Geology Nos. 32003, 32015. (p. 612)

7, 8, 12—Oistodus sp. University of Texas Bureau of Economic Geology Nos. 32005, 32006, 32010. (p. 612)

9—Ligonodina sp. University of Texas Bureau of Economic Geology No. 32007. (p. 612)

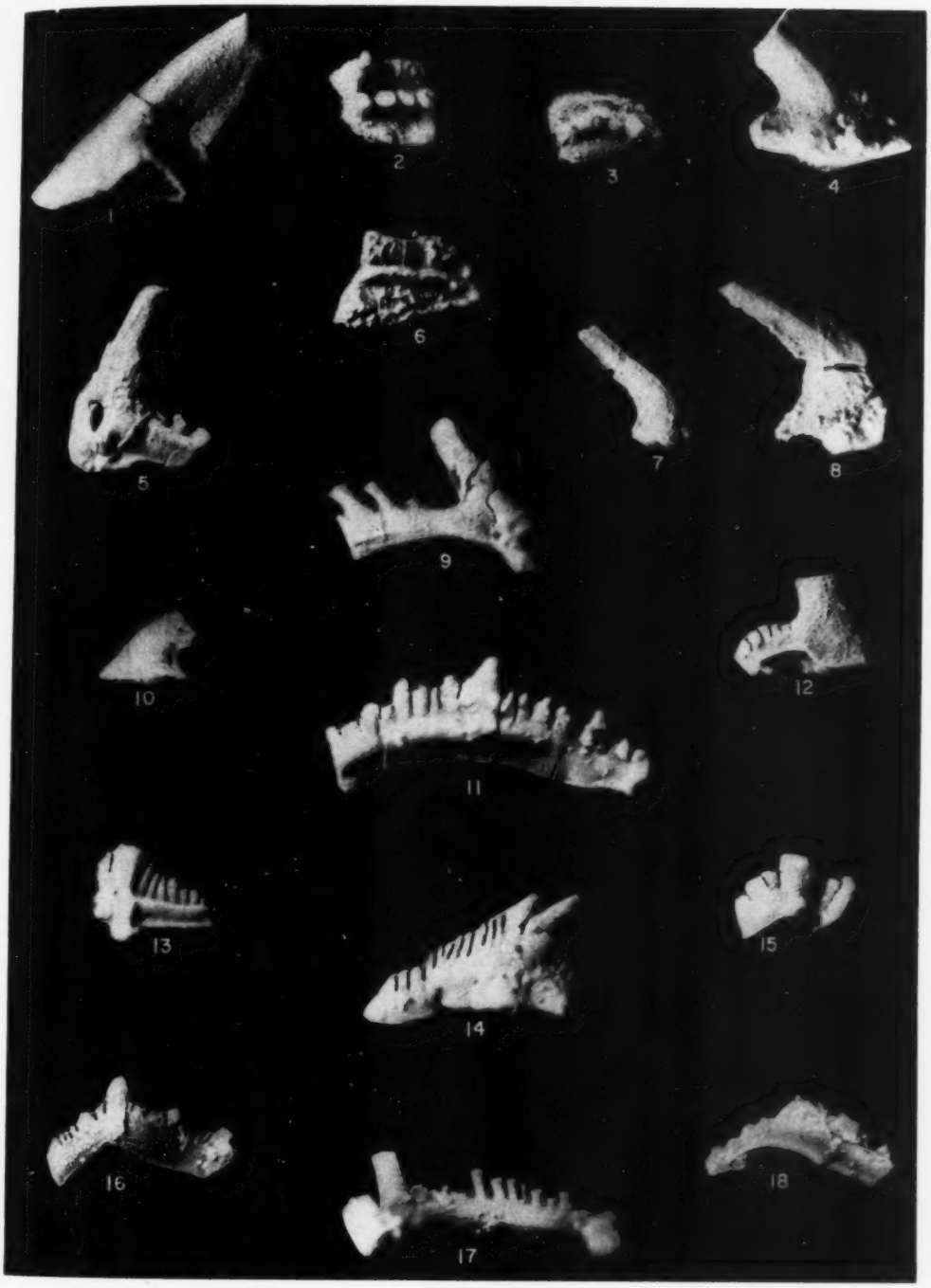
11, 18—Bryantodus sp. University of Texas Bureau of Economic Geology Nos. 32009, 32016. (p. 612)

13—Bryantodus? sp. University of Texas Bureau of Economic Geology No. 32011. (p. 612)

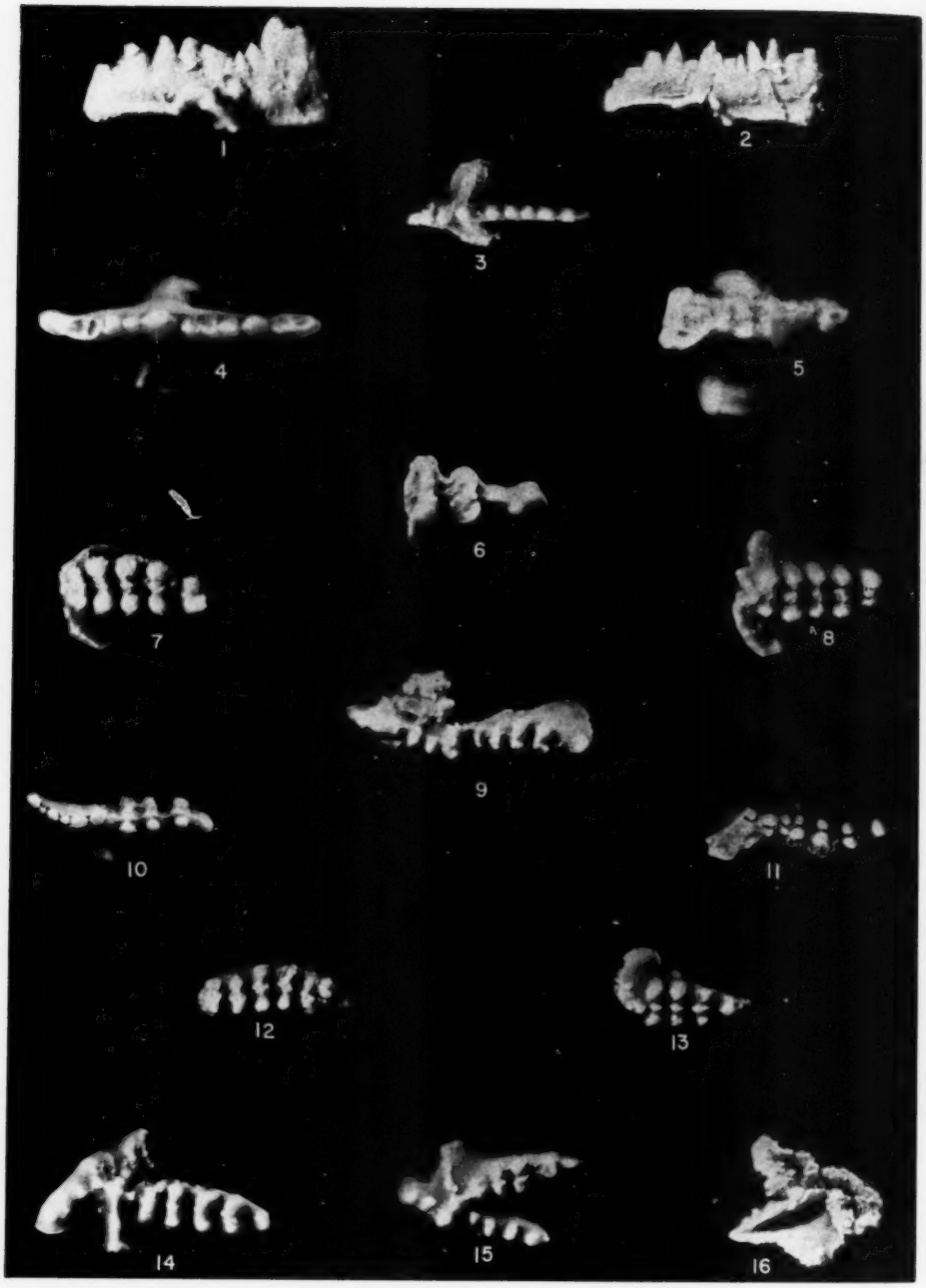
14—Ozarkodina sp. University of Texas Bureau of Economic Geology No. 32012. (p. 612)

15—Hibbardella sp. University of Texas Bureau of Economic Geology No. 32013. (p. 612)

16—Centrognathodus? sp. University of Texas Bureau of Economic Geology No. 32014. (p. 612)



Graves, Devonian Conodonts from Texas



Graves, Devonian Conodonts from Texas

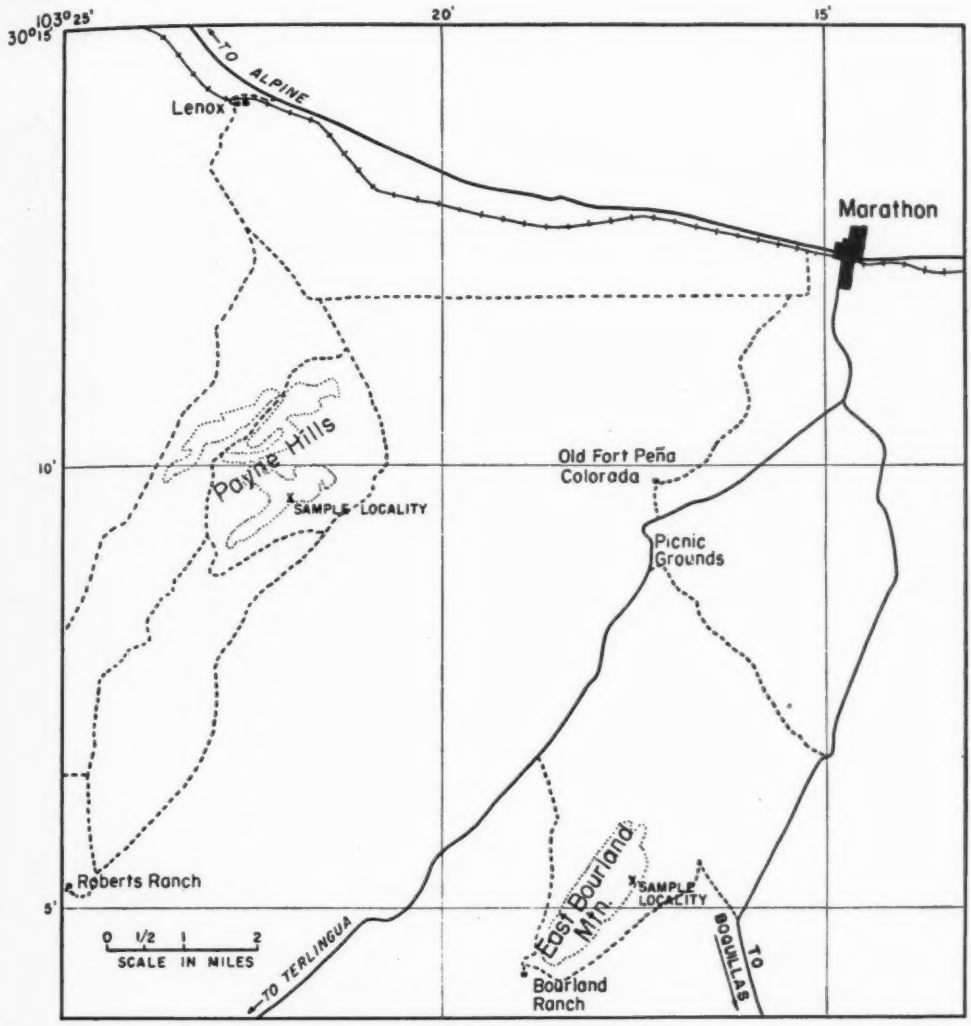


FIG. 1—Index map of northern Brewster County, Trans-Pecos, Texas. Dotted lines in Payne Hills and East Bourland Mountain approximately outline areas of outcrop of Caballos novaculite. (Drawn from King, 1937, pl. 24.)

EXPLANATION OF PLATE 81

Limestone fauna. All figures ×30.

FIGS. *1, 3–5*—*Spathognathodus aculeatus* Branson and Mehl. University of Texas Bureau of Economic Geology Nos. 32017, 32019–32021. (p. 612)

2—*Spathognathodus stabilis* Branson and Mehl. University of Texas Bureau of Economic Geology No. 32018. (p. 612)

6–8, 12, 13—*Icriodus symmetricus* Branson and Mehl. University of Texas Bureau of Economic Geology Nos. 32022–32024, 32028, 32029. (p. 612)

9, 14–16—*Icriodus latericrescens* Branson and Mehl. University of Texas Bureau of Economic Geology Nos. 32025, 32030–32032. (p. 612)

10, 11—*Icriodus curvatus* Branson and Mehl. University of Texas Bureau of Economic Geology Nos. 32026, 32027 (p. 612)

siliceous shales on East Bourland Mountain (pl. 79) are molds and complete specimens and include the following species:

Hindeodella? sp.
Ligonodina? sp.
Ozarkodina sp.
Palmatolepis perlobata Ulrich and Bassler
P. subperlobata Branson and Mehl
Palmatolepis cf. *P. delicatula* Branson and Mehl
Palmatolepis sp.
Spathognathodus? sp.
Synprioniodina sp.

Figures 1–16 and 18 of plate 79 are of castings produced by pouring nitrocellulose plastic into the natural molds in the shale. These castings were whitened with ammonium chloride and photographed. The plastic was prepared by the formula published by Buehler (1948, p. 71) and produced excellent reproductions of the natural mold surfaces.

Conodonts from a limestone lens in the Payne Hills (pls. 80 and 81) were obtained by digestion of samples of the limestone with approximately 2N acetic acid and include the following species:

Bryantodus sp.
Bryantodus? sp.
Centrognathodus? sp.
Hibbardella sp.
Icriodus curvatus Branson and Mehl
I. latericrescens Branson and Mehl
I. symmetricus Branson and Mehl
Ligonodina sp.
Ligonodina? sp.
Oistodus inclinatus Branson and Mehl
Oistodus sp.
Ozarkodina sp.
Palmatolepis sp.
Spathognathodus aculeatus Branson and Mehl
S. stabilis Branson and Mehl

On the basis of comparative occurrences of *Icriodus* and *Palmatolepis*, the conodont faunas shown here are interpreted as Devonian in age (Branson and Mehl, 1938; Ellison, 1946; Haas, 1947). The Caballos conodont fauna is probably of the same age as the faunas of the Grassy Creek shale of Missouri (Branson and Mehl, 1944), the Huron-lower Ohio shale of south-central Ohio (Haas, 1947), the Woodford shale of Oklahoma (Cooper, 1931) and the subsurface Woodford of west Texas and southeast New Mexico (Ellison, 1950). This is some of the first convincing fossil evidence on the age of the Caballos and on the basis of similarities of conodont faunas, the upper part of the Caballos novaculite is assigned to the Upper Devonian.

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MICROFAUNA OF THE PENNSYLVANIAN GLEN EYRIE FORMATION, COLORADO

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ABSTRACT—Fifteen species of ostracodes, including two new species and one new variety, and five species of conodonts make up the Glen Eyrie microfauna. Thirteen of these are unknown in rocks older than Cherokee, and three are known only from the Morrow. The fauna is concluded to be at least as young as Des Moines and the Morrow forms probably are present because of facies similarities of the Glen Eyrie and the lowermost Pennsylvanian of Oklahoma.

INTRODUCTION

THIS microfauna was collected from very near the base of the Glen Eyrie formation in the Manitou Embayment west of Colorado Springs, Colorado. Well-preserved ostracodes and conodonts were found only in two feet of gray shale occurring six feet above the contact with the underlying Madison limestone. Fragmental remains of brachiopods, bryozoans, and pelmatozoans occur associated with them and also in the overlying five feet of shale.

Poorly preserved brachiopods occur in a very impure two-foot limestone bed 157 feet above the base of the formation. Other fragmental fossils are sparsely distributed in zones 168 and 346 feet above the base of the formation. A detailed description of the formation and of its stratigraphic relationships has been previously published (McLaughlin, 1947, pp. 1942–47).

All specimens herein described have been deposited in the collections of the Geology Department of Montana State University (MSU), Missoula, Montana.

The exposure from which the microfauna was collected is located in Sec. 28, T. 13 S., R. 67 W., El Paso County, Colorado. It is in a shallow cut on the east side of the Rampart Range road 500 feet north of the turnoff of the Black Canyon Loop road.

The writer wishes to express his appreciation to Dr. H. V. Howe of Louisiana State University for the excellent photographs of the ostracodes. The loan of specimens by H. B. Willman of the Illinois Geological Survey and by Betty Kellett Nadeau of Washington University (St. Louis) was of great assistance in making some of the final identifications. Although the writer disagrees with Mrs. Nadeau regarding the age of the fauna, he is indebted to her for helpful suggestions and criticism.

AGE OF FAUNA

After preliminary study, the writer indicated his belief that the Glen Eyrie fauna is probably of Des Moines age (McLaughlin, 1947, pp. 1973–75). More detailed study seems to have corroborated this conclusion and the fauna is now believed to establish definitely the equivalence of the Glen Eyrie to some part of the Des Moines Stage.

Kellett (1948, p. 129) stated that the Glen Eyrie ostracodes are "probably Atoka-Lampasas in age; they could only be older, or slightly younger, Morrow or earliest Cherokee in age."

The writer recognizes that the conspicuous ornamentation characteristic of many Glen Eyrie ostracodes is similar to that of many early Pennsylvanian forms from Oklahoma. Also *Monoceratina ardmorensis* and *Polytylites wapanuckensis* have not been reported from strata younger than the Morrow, and the Glen Eyrie specimens do not differ significantly from the types. These two species, however, and the conodont, *Polygnathodella ouachitensis*, are the only previously described forms in the Glen Eyrie fauna which have been considered to be restricted to the Morrow. On the other hand, thirteen species have not been reported from beds older than Cherokee. Only two other Glen Eyrie species, *Bairdia*

oklahomaensis, and *Geisina arcuata*, known from upper Des Moines or lower Missouri Stages, have been reported from rocks older than Cherokee. On the whole, therefore, this fauna indicates that the fauna cannot be older than Des Moines.

Evidence has been presented that the Glen Eyrie formation was deposited in a subsiding trough or basin immediately adjacent to the "ancestral Rocky Mountains" (McLaughlin, 1947, pp. 1975–1977). The environment of deposition in this trough may have been very similar to the earlier Pennsylvanian environment in the Ouachita geosyncline. If so, some "typical Wapanucka-Johns Valley" species might have persisted for a considerable time in this environment to which they were apparently well adapted.

SYSTEMATIC DESCRIPTIONS

Class CRUSTACEA
Superorder OSTRACODA Latreille
Family BAIRDIIDAE Sars, 1887
Genus BAIRDIA McCoy, 1846

BAIRDIA OKLAHOMAENSIS Harlton

Plate 82, figs. 19, 20

Bairdia oklahomaensis HARLTON, 1927, Jour. Paleontology, vol. 1, p. 209, pl. 33, fig. 7; Glenn formation, Okla.

Bairdia oklahomaensis, COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 48, pl. 3, figs. 18–20; Caseyville (Morrow) to lower McLeansboro (Kansas City), Ill. (Includes complete synonymy.)

The abundant Glen Eyrie specimens of this long-ranging species are identical to Harlton's types in all but one respect. The surfaces of the valves are not "evenly

TABLE I.—REPORTED STRATIGRAPHIC RANGES OF GLEN EYRIE SPECIES

Stages*	Spring-eran	Mor-rowan	Atokan	Desmoinesian		Missourian					Virgilian		
Groups and Formations		Johns Valley and Wapanucka formations (Fulda limestone of Illinois)	Atoka and upper Dornick Hills formations	Cherokee group	Marmaton group	Bourbon gr.	Bronson gr.	Kansas City gr.	Lansing gr.	Pedee gr.	Douglas gr.	Shawnee gr.	Wabaunsee gr.
Ostracodes†													
Monoceratina ardmorensis		X											
Polytylites wapanuckensis		XXX											
Bairdia oklahomaensis		XXX	XX	X	X	X	X	X					
Geisina arcuata		X	X										
Hollinella kellettae				XX	XX								
Microparaparchites cornutus				XXX									
Cavellina cf. C. fittsi				X								X	X
Kirkbya clarocarinata					X								
Amphissites robustus					XX	X	X	X					
Bairdia hoxbarensis					XX	X	X	X					
Microparaparchites brazoensis					XX								
Glyptopleura aff. G. coryelli					X			X					
Amphissites congruens										X			
Conodonts													
Polygnathodella ouachitensis		X											
Idiognathodus magnificus				X				X					
Idiognathodus delicatus				X	X	X	X	X	X				
Cavusgnathus giganta				X	X	X	X	X	X	X	X	X	X
Cavusgnathus flexa							X	X	X	X	X	X	X

* Moore, R. C., and Thompson, M. L., 1949, Am. Assoc. Petrol. Geol., Bull., vol. 33, p. 288.
† The order of listing is designed to facilitate comparison of stratigraphic occurrences.

convex" and in dorsal view Glen Eyrie specimens show a distinct parallelism of the lateral margins. Similar flattening seems to be well-developed in some Illinois specimens figured by Cooper. It is too characteristic of the many Glen Eyrie specimens to be attributed to post-burial compression.

Length, 1.3 mm.; height, 0.75 mm.; width, 0.6 mm.

Figured specimens.—MSU No. 5001.

BAIRDIA HOXBARENSIS Harlton
Plate 82, fig. 18

Bairdia hoxbarensis HARLTON, 1927, Jour. Paleontology, vol. 1, p. 211, pl. 33, fig. 12; Hoxbar formation, Okla.

Bairdia hoxbarensis, COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 46, pl. 2, figs. 43, 44; lower McLeansboro (Pawnee to Bronson), Ill. (Includes complete synonymy).

This species is less numerous in the Glen Eyrie collections than is *Bairdia oklahomaensis*. Only right valves have been found. They appear to be identical to Harlton's types except for a very slight concavity of the anterodorsal slope.

Length (of right valve), 1.05 mm.; height 0.5 mm.

Figured specimen.—MSU No. 5002.

Family CYTHERIDAE Baird, 1850
Genus MONOCERATINA Roth, 1928
MONOCERATINA ARDMORENSIS (Harlton)
Plate 82, figs. 5, 6

Cythereis? ardmorensis HARLTON, 1927, Jour. Paleontology, vol. 1, p. 211, pl. 33, figs. 14 a–c; lower Glenn formation, Okla. —— HARLTON, 1929, American Jour. Sci., ser. 5, vol. 18, p. 270, pl. 2, figs. 18 a–b; Wapanucka limestone and Dornick Hills group, Okla.

Monoceratina ardmorensis, HARLTON, 1933, Jour. Paleontology, vol. 7, p. 21, pl. 7, figs. 14 a–b; Johns Valley shale, Okla. ——, COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 39, pl. 1, fig. 9; Fulda limestone (Wapanucka), Ill.

The three Glen Eyrie specimens are slightly smaller than Harlton's Johns Valley forms but they appear to be identical in general outline, form ratios, the development of ventral flanges, and orientation of the ventral spines. They are less acuminate posteriorly than the specimen figured by Cooper.

Length, 0.58 mm.; height, 0.30 mm.; width (maximum, tip-to-tip of spines), 0.40 mm.

Figured specimens.—MSU No. 5003.

Family CYTHERELLIDAE Sars, 1865
Genus CAVELLINA Coryell, 1928
CAVELLINA cf. C. FITTSI Kellett
Plate 82, figs. 26, 27

Cavellina fittsi KELLETT, 1935, Jour. Paleontology, vol. 9, p. 147, pl. 18, figs. 2a–3g; Shawnee and Wabaunsee groups, Kan.

——, COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 72, pl. 9, figs. 21–27; lower Carbondale (Cherokee), Ill.

In lateral view posteroventral slope straight, maximum length well above mid-height, anterior bluntly but evenly rounded. Anterior and posterior dorsal slopes very gently curved, meeting at a barely perceptible angle just posterior to mid-length. Overlap of right valve over left strong dorsally and ventrally, moderate posteriorly, very slight anteriorly. In dorsal view, maximum thickness in posterior one-third. Dorsal overlap by right valve decreases abruptly at about middle of anterior half offsetting the margin. Outer surface without ornamentation. Edge of right valve strongly grooved to receive peripheral flange of left valve.

Length, 1.25 mm.; height, 0.95 mm.; width, 0.60 mm.

Figured specimens.—MSU No. 5004.

Family KLOEDENELLIDAE Ulrich and Bassler, 1923
Genus GEISINA Johnson, 1936
GEISINA ARCUATA (Bean)
Plate 82, fig. 8

Cypris arcuata BEAN, 1836, Ann. Mag. Nat. Hist., vol. 9, p. 377, woodcut, fig. 55.

Beyrichia arcuata JONES and KIRKBY, 1886, Geol. Mag., vol. 3, p. 438, pl. 12, figs. 12–14.

Jonesina arcuata ULRICH & BASSLER, 1908, Proc. U. S. Nat. Mus. No. 1646, vol. 35, pl. 44.

Jonesina arcuata HARLTON, 1927, Jour. Paleontology, vol. 1, p. 205, pl. 32, figs. 6 a–c; Lower Glenn, Okla.

—— KNIGHT, 1928, Jour. Paleontology, vol. 2, p. 243, pl. 31, figs. 6 a–b; pl. 33, fig. 6; Upper Fort Scott, Mo.

—— BRADFIELD, 1935, Bull. Am. Paleontology, vol. 22, p. 38, pl. 2, fig. 6; Dornick Hills group, Okla.

Geisina jolliffina COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 110, pl. 18, figs. 3, 4; Jamestown (Marmaton), Ill.

Carapace short, subovate, hinge-line straight but dorsal margin appears slightly sinuous because of high tumidity of valves. Ends subequally rounded, anterior slightly higher than posterior, ventral margin

broadly convex. A deep narrow sinus partially separates the more tumid anterior three-fifths of valve from a low indistinct posterior node which is followed posteriorly by a second, shallower sinus. Surface finely pitted, margins bordered by smooth rounded indistinct flange.

Length, 0.75 mm.; height, 0.5 mm.

Figured specimen.—MSU No. 5005.

The specimens upon which Cooper erected *G. jolliffina* differ from Glen Eyrie forms only in possessing a stronger marginal flange, which Cooper described as being more prominent than on Bradfield's Oklahoma forms. The similarity of the Glen Eyrie specimens with those described from Oklahoma, Missouri, and Illinois is too close to warrant recognition of more than one species.

Although Kellett (1948 p. 129) stated that *G. arcuata* is quite characteristic of Bradfield's lower Dornick Hills fauna, it occurs in the Des Moines series in Fort Scott (Knight, 1928, p. 243) and Jamestown beds (Cooper, 1946, p. 110) respectively, of Missouri and Illinois.

Family GLYPTOPLEURIDAE Girty, 1910
Genus GLYPTOPLEURA Girty, 1910
GLYPTOPLEURA aff. G. CORYELLI Harlton
Plate 82, fig. 17

Glyptopleura spinosa HARLTON, 1929, Texas Univ. Bull. 2901, p. 148, pl. 1, fig. 18; Canyon group, Texas.
—— DELO, 1930, Jour. Paleontology, vol. 4, p. 162, pl. 12, fig. 12; subsurface Schleicher County, Texas.
—— DELO, 1931, Washington Univ. (St. Louis) Studies, new ser., Sci. and Tech. no. 5, p. 44, pl. 4, fig. 4; subsurface, 4100 feet, Hamilton County, Kan.
Glyptopleura coryelli HARLTON, in Coryell and Brackmier, 1931, American Mid. Natur., vol. 12, p. 513, pl. 2, fig. 18, Canyon formation, Texas.
—— JOHNSON, 1936, Nebraska Geol. Survey Paper 11, p. 36, pl. 3, fig. 15; Stanton formation, Nebr.
—— COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 79, pl. 10, figs. 43–45; Gimlet and Millersville formations, Ill.

Carapace tumid, subquadrate, posterior rounded, anterior irregularly rounded and blunter, hinge line straight, ventral margin broadly convex, somewhat flattened in midportion. Pit slightly above and behind midpoint of carapace. Four major ribs, one bifurcating just above and posterior to pit, terminating anteriorly in a low posteriorly projecting spine. Lowest of three ribs below pit terminating anteriorly in a low spine or node. A short rib is located in posterodorsal corner and a second just anterior to pit. Two ribs of intermediate length occur on ventral portion of the valve. All ribs slightly inclined, converge posteriorly.

Length, 1.0 mm.; height, 0.45 to 0.55 mm.

Figured specimen.—MSU No. 5006.

The numerous well-preserved Glen Eyrie specimens show considerable variations in curvature, sinuosity and number of ribs. One small and obviously immature specimen has only three widely spaced ribs below the pit, and the bifurcating rib and the second rib below the pit terminate in heavier spines than are present on more mature specimens. Most of them differ from Harlton's types and from *G. coryelli* (or *G. spinosa*) described and figured by Delo (1930, p. 162), Coryell and Brackmier (1931, p. 513), and Cooper (1946, pl. 12), in possessing five ribs below the pit rather than four, and in being somewhat more spinose.

Family HEALDIIDAE Harlton, 1933
Genus HEALDIA Roundy, 1926
HEALDIA PUNCTATA McLaughlin, n. sp.
Plate 82, figs. 21–23

Carapace subovate, dorsal margin arched to sub-acuminate, ventral margin straight to very slightly convex. Ends nearly equally rounded, posterodorsal slope straight, anterodorsal slope very slightly concave. Greatest height central to very slightly anterior. Overlap by left valve slight posteriorly. Posterior ridge prominent, nearly straight, moderately long, resulting in widely spaced posterior spines. Ridge with four minute elongate slits on anterior slope.

Length, 0.8 mm.; height, 0.45 mm.; form ratio, 1.77.

Figured holotype.—MSU No. 5007; paratype, MSU No. 5007-A.

This differs from other described species of the genus in the presence of slits on the anterior slope of the posterior ridge. Roundy (1926, p. 12) reported that "one species (of *Healdia*) has a small punctate area in front of the two spines." *H. punctata* most

closely resembles *H. marginata* Harlton in outline and in prominence of the posterior ridge.

HEALDIA UNISPINOSA McLaughlin, n. sp.
Plate 82, figs. 24, 25

Carapace subovate, dorsal margin arched to sub-acuminate, ventral margin straight to slightly convex, anterior end rounded, posterior end rounded to sub-acuminate, anterodorsal and posterodorsal slopes typical of the genus. Maximum height central to slightly posterior, maximum thickness at posterior swelling. Anterior portion of valves smoothly convex, posterior swelling rounded and indistinct, terminating ventrally in a large, strong, posteriorly projecting spine.

Length, 0.70 mm.; height, 0.45 mm.; form ratio, 1.52.

Figured holotype.—MSU No. 5008; paratype, MSU No. 5008-A.

This differs from other species of the genus in possessing a single ventral spine, thus resembling certain species of *Waylandella*. This resemblance and the typical *Healdia*-like outline of species such as *W. bythocyproidea* (Warthin) figured by Cooper (1946) suggests that there may be a series of intergradations linking the two genera, or that certain species of *Waylandella* should be referred to *Healdia*.

Family HOLLINIDAE Swartz, 1936
Genus HOLLINELLA Coryell, 1928
HOLLINELLA KELLETTAE Knight
Plate 82, fig. 7

Hollina ulrichi KNIGHT, 1928, Jour. Paleontology, vol. 2, p. 237, pl. 31, figs. 4 a–b; Labette formation, Mo.

Hollinella kellettae KNIGHT in Kellett, 1933, Jour. Paleontology, vol. 7, p. 70.

Hollinella kellettae, COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 92, pl. 14, figs. 6–10; Carbondale (upper Cherokee and lower Marmaton), Ill. (Includes intervening synonymy and discussion.)

Cooper's description: "Carapace large, with pronounced backward 'swing'; hingeline long, straight, right valve has short spine on posterior end and a much longer, slightly curved spine on anterior end; anterior node of large diameter stands high above shell surface and carries the same markings as rest of shell, namely granulations and numerous short rounded spines; posterior node about half as thick, merges with shell surface postero-ventrally; frill wide, flaring, incurved for half its length posteriorly, terminated near anterior end by large spine.

"Length (figs. 7, 8), 1.06 mm.; height, 0.60 mm."

This description could have been based on Glen Eyrie specimens but, in addition, these exhibit radiating structure of the frill and a low but pronounced swelling of the carapace just below the two nodes. The form ratios of the Illinois and Colorado specimens are identical, and it is on this basis that the species is distinguished from *H. oklahomaensis* and *H. ulrichi*.

Length, 1.0 mm.; height, 0.55 mm.; form ratio, 1.81.

Figured specimen.—MSU No. 5009.

Family KIRKBYIIDAE Ulrich and Bassler, 1923
Genus AMPHISSITES Girty, 1910
AMPHISSITES CONGRUENS Cooper
Plate 82, figs. 11, 12, 13?, 14?, 16?

Amphissites congruens COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 99, pl. 15, fig. 43; McLeansboro group (Lansing), Ill.

Cooper's description: "Carapace subquadrate, dorsal and ventral margin straight and parallel, ends rounded; inner carina low and indistinct anteriorly, becoming more prominent, and gradually diverging from outer carina around ventral margin to the postero-ventral angle, where it disappears; posterior swelling distinct, surmounted by a false carina formed by ridge joining two rows of reticulations; median node fairly large, irregular in outline, located above and forward of ovate pit; axis of pit deflected to anterior, surface covered by reticulations of irregular shape, medium size, tending toward a regular alignment near the major features of shell sculpture.

"Length, 0.82 mm.; height, 0.48 mm."

The Glen Eyrie specimens include forms identical to the types. They are associated, in an essentially unbroken series with others, (Plate 82, figs. 13, 14) whose inner carinae are much less developed and tend to parallel the outer margin, and on which the median node and posterior swelling are much less

distinct. The latter might be considered variants of *A. congruens*. They also resemble *Ectodemites geneae* Roth (1929) but differ in having more sharply delimited pits; higher, though well-rounded, median nodes and posterior shoulders; and indistinct carinae fairly high on the posterior and posteroventral margins.

Figured specimen.—MSU No. 5010.

AMPHISSITES ROBUSTUS RADIATUS
McLaughlin, n. var.
Plate 82, fig. 10

Amphissites robustus COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 100, pl. 15, figs. 34–36; McLeansboro group (upper Marmaton to Kansas City), Ill.

The reticulations of the Glen Eyrie specimens form a distinctly radiating pattern distorted only by the median node which is very slightly forward of the anteriorly inclined ovate pit. Posterior swelling moderate, surmounted by a slightly curving carina; anterior carina indistinct, curving to parallel the strong inner flange to the ventral margin of the pit. Anterior and posterior swellings connected dorsally by a slender smooth carina which stands slightly above the actual dorsal margin.

Length, 1.0 mm.; height, 0.52 mm.

Figured homeotype.—MSU No. 5011.

The radiating reticulate pattern and the slightly inclined pit are the chief features distinguishing this variety from *A. robustus* as described by Cooper. In all major respects, however, the Glen Eyrie specimens are too similar to Cooper's types to warrant specific separation.

Genus POLYTYLITES Cooper, 1941
POLYTYLITES WAPANUCKENSIS (Harlton)
Plate 82, fig. 15

Amphissites wapanuckensis HARLTON, 1929, American Jour. Sci., ser. 5, vol. 8, p. 257, pl. 1, figs. 4 a–b; Wapanucka limestone, Okla. —— HARLTON, 1933, Jour. Paleontology, vol. 7, p. 108, pl. 16, figs. 21, 22; Fulda limestone (Wapanucka), Ill.

All Glen Eyrie specimens have the central part of the ventral margin straight and nearly parallel to the dorsal margin. Some have the inner carina rather sharply inclined posteriorly, on others it parallels the ventral margin, and a few have it broadly curved. Posterior end of all specimens less rounded and slightly higher than the anterior.

Length, 0.65 to 0.90 mm.; height, 0.35 to 0.50 mm.

Figured specimen.—MSU No. 5012.

Genus KIRKBYA Jones, 1859
KIRKBYA cf. C. CLAROCARINATA Knight
Plate 82, fig. 9

Kirkbya clarocarinata KNIGHT, 1928, Jour. Paleontology, vol. 2, p. 258, pl. 32, fig. 2, Pl. 33, fig. 2; upper Fort Scott, Mo.
Kirkbya clarocarinata KNIGHT, in Cooper, 1946, Illinois Geol. Survey Bull. 70, p. 106.

Carapace elongate, subquadrate, hinge-line straight, cardinal angles very acute, posterior end bluntly rounded, anterior end sloping very steeply from cardinal angle to curve into very slightly convex ventral margin. Surface coarsely reticulate with outer reticulations tending to parallel inner flange which is very strong and which is separated from outer margin by four rows of reticulations. Median pit slightly in front of mid-point, very little larger than surrounding reticulations. Shoulder consists only of a gentle swelling between mid-height and dorsal margin.

Length, 0.82 mm.; height, 0.42 mm.; width, 0.25 mm.

Figured specimen.—MSU No. 5013.

The Glen Eyrie specimen differs from Knight's type only in the somewhat blunter ends and less convex ventral margins. However, the acute cardinal angles, the highly-placed inner flange, and the low shoulder which is slightly more tumid anteriorly seem to indicate specific identity

Family LEPERDITELLIDAE Ulrich and Bassler, 1906
Genus MICROPARAPARCHITES Croneis and Gale, 1939
MICROPARAPARCHITES BRAZOENSIS (Coryell and Sample)
Plate 82, figs. 1, 2

Paraparchites brazoensis CORYELL and SAMPLE, 1932, American Mid. Natur., vol. 13, p. 249, pl. 24, fig. 5; East Mountain shale, Texas.
Microparaparchites brazoensis, COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 118, pl. 20, figs. 16–18; Upper Marmaton, Ill. (Includes synonymy.)

Carapace small, subovate, hinge-line straight but in lateral view dorsal margin

is very slightly convex, ventral margin regularly and broadly convex and merging smoothly with rounded ends. Antero-dorsal angle very obtuse (135°), anterior end very broadly rounded; postero-dorsal angle less obtuse (115°), posterior end less broadly rounded, producing a forward "swing" of the carapace with respect to its hingeline. Maximum thickness in posterior one-half. Postero-dorsal spines emerging smoothly from surface and projecting upward and outward from slightly in front of and below the angle.

Length, 0.65 mm.; height 0.44 mm.; Length-height ratio, 1.46.

Figured specimens.—MSU No. 5014.

The spines of the Glen Eyrie forms are less prominent than those of the types and of the Illinois specimens but the general outline and length-height ratio are essentially the same.

MICROPARAPARCHITES CORNUTUS Cooper
Plate 82, figs. 3, 4

Microparaparchites cornutus COOPER, 1946, Illinois Geol. Survey Bull. 70, p. 118, pl. 20, figs. 13–15; Liverpool (Cherokee), Ill.

Carapace small, semiovate, hinge-line straight but dorsal margin is very slightly convex, ventral margin broadly convex curving smoothly into well-rounded ends. Anterodorsal angle very obtuse, posterodorsal angle nearly 90°, forward "swing" of carapace moderate. Long hollow spines flaring broadly from posterodorsal surface, projecting strongly upward. Surface smooth, maximum thickness slightly behind midpoint, only moderately tumid.

Length, 0.54 mm.; height, 0.35 mm.

Figured specimens.—MSU No. 5015.

The Glen Eyrie specimens differ from the type in being slightly less high and the irregularity of the dorsal margin is not as pronounced as on the specimens figured by Cooper.

CONODONTS

Genus IDIOGNATHODUS Gunnell, 1931
IDIOGNATHODUS DELICATUS Gunnell
Plate 83, figs. 8–11

Idiognathodus delicatus GUNNELL, 1931, Jour. Paleontology, vol. 5, p. 250, pl. 29, figs. 23, 24, 25; Fort Scott limestone, Mo.

Idiognathodus delicatus, ELLISON, 1941, Jour. Paleontology, vol. 15, p. 134, pl. 22, figs. 31–36; revised occurrence, Cherokee shale to Stanton, Kan.; Mineral wells and Graford formations, Texas. (Includes synonymy to 1941.)

The Glen Eyrie specimens all conform closely to Ellison's revised description except that the lateral accessory lobes are less developed. The inner lobes bear from one to four nodes, the outer lobes, one or two. The posterior portions of the platforms bear five or six transverse ridges normal to the platform axis. No specimens with complete blades were found, but the extension of the blade onto the anterior portion of the platform as a carina is a uniform characteristic of all specimens observed. These specimens conform to Ellison's concept of immature forms of the species.

Figured specimens.—MSU No. 5016.

IDIOGNATHODUS MAGNIFICUS Stauffer and Plummer
Plate 83, figs. 12–14

Idiognathodus magnificus STAUFFER and PLUMMER, 1932, Univ. of Texas Bull. 3201, p. 46, pl. 4, figs. 8, 18, 20.

Idiognathodus magnificus, ELLISON, 1941, Jour. Paleontology, vol. 15, p. 135, pl. 23, figs. 2, 4, 7, 10; revised occurrences, Des Moines and Missouri series, also Grafford and Mineral Wells formations, Texas, and Boggy shale, Okla. (Includes synonymy to 1941.)

Glen Eyrie specimens referred to this species are distinguished from *I. delicatus* primarily by the close incorporation of the outer lobes into their platforms and by the flaring lateral surfaces of the platforms. The lesser length-width ratio of the Glen Eyrie specimens is noticeable but not pronounced. The carina forming the posterior extension of the blade is short. The maximum number of nodes noted on any inner accessory lobe is six. No more than six transverse ridges occur on any specimen.

Several Glen Eyrie specimens appear to be identical to one figured by Ellison from the Cherokee. One specimen is almost identical to *I. cuneiformis* Gunnell which Ellison placed in synonomy with *I. magnificus*.

Figured specimens.—MSU No. 5017.

The abundance of specimens of *I. delicatus* and *I. magnificus* and the absence of gondolellids is consistent with the Des Moines

age of the Glen Eyrie fauna (Ellison, 1941, pp. 109–110).

Genus CAVUSGNATHUS Harris and Hollingsworth, 1933
CAVUSGNATHUS FLEXA Ellison
Plate 83, fig. 2

Cavusgnathus flexa ELLISON, 1941, Jour. Paleontology, vol. 15, p. 126, pl. 21, figs. 42, 43, 46, Bronson (lower Missouri series) to Big Blue.

Ellison's description: "Platform long, lanceolate, posteriorly rounded; axis of platform moderately flexed inward; inner and outer parapets ornamented with regularly spaced parallel transverse ridges obsolescent toward the deep oral trough and slightly radiating at the posterior end; outer parapet continued into blade bearing laterally compressed subequal denticles; aboral attachment scar very slender, moderately deep, widely flared and flexed to correspond to flexure of platform axis; sides of platform almost vertical on outer side but constricted on the inner side so that the inner parapet overhangs."

Glen Eyrie specimens appear to differ from Ellison's types only in being less flexed longitudinally and in having a less pronounced inward flare from the deepest part of the aboral attachment scar.

Figured specimen.—MSU No. 5018.

CAVUSGNATHUS GIGANTA Gunnell
Plate 83, figs. 3, 4, 6, 7

Cavusgnathus gigantus GUNNELL, 1933, Jour. Paleontology, vol. 7, p. 286, pl. 31, figs. 7, 8; Chanute shale (Kansas City group), Mo.
Cavusgnathus giganta, ELLISON, 1941, Jour. Paleontology, vol. 15, p. 126, pl. 21, figs. 44, 45, 49; Cherokee to Big Blue Series.

Glen Eyrie specimens are essentially identical to those described by Gunnell and Ellison although the aboral attachment scars appear to be slightly shallower than in specimens figured by Ellison.

Figured specimens.—MSU No. 5019.

Genus POLYGNATHODELLA Harlton, 1933
POLYGNATHODELLA OUACHITENSIS Harlton
Plate 83, figs. 1, 5

Polygnathodella ouachitensis HARLTON, 1933, Jour. Paleontology, vol. 7, p. 15, pl. 4, figs. 14 b–c, probably not 14 a; Johns Valley shale, Okla.

Platform narrowly lanceolate in outline, posterior narrow and sharply acuminate. Oral surface traversed by distinct chevron-like ridges, platform with shallow median trough. Outer parapet of platform incurved, extended anteriorly as a denticulate blade which is aligned with median trough of platform. Lateral surfaces of platform broadly flaring.

Branson and Mehl (1941, p. 103) stated that this genus is unknown from Upper Mississippian formations and the Cherokee shale or its equivalents, but that it has been collected from the Wapanucka, Johns Valley, lower Dornick Hills, Hartville, and Quadrant formations.

Figured specimens.—MSU No. 5020.

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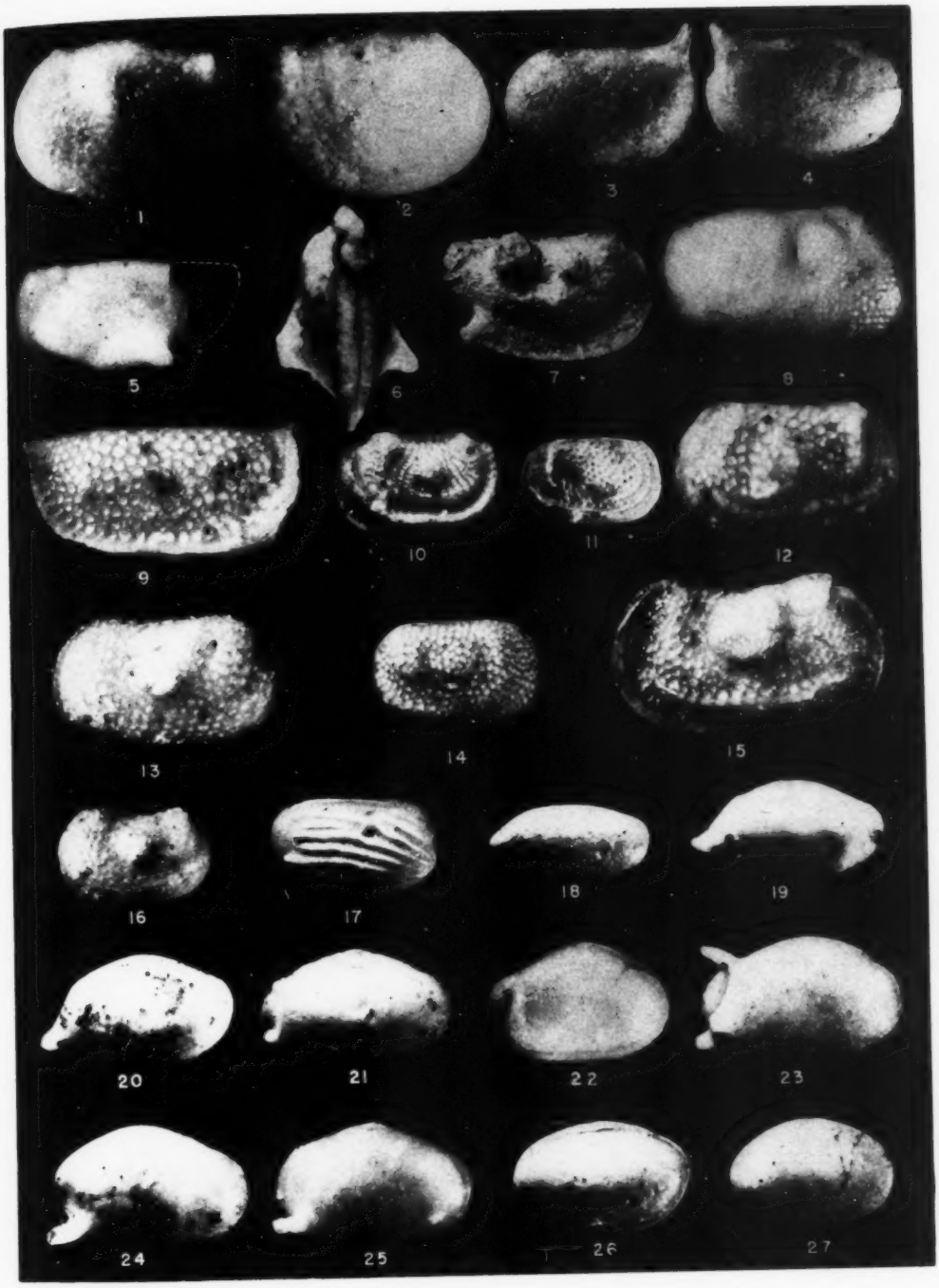
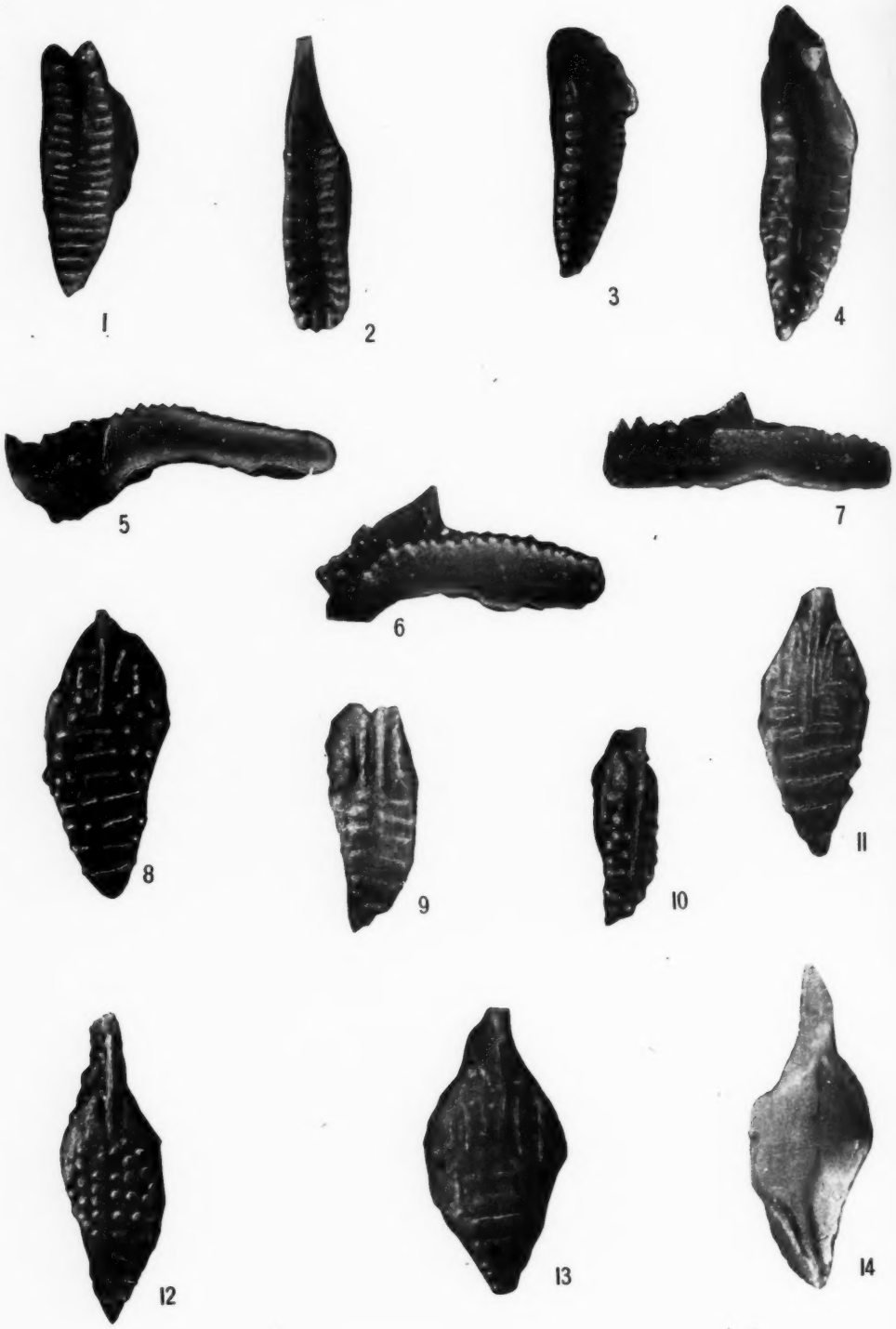
EXPLANATION OF PLATE 82

FIGS. *1, 2*—*Microparaparchites brazoensis* (Coryell and Sample). *1*, left valve; *2*, right valve; ×45. (p. 618)
3, 4—*Microparaparchites cornutus* Cooper. *3*, left valve; *4*, right valve; ×45. (p. 619)
5, 6—*Monoceratina ardmorensis* (Harlton). *5*, left valve; *6*, dorsal view; ×45. (p. 615)
7—*Hollinella kellettae* Knight. Left valve; ×25. (p. 617)
8—*Geisina arcuata* (Bean). Left valve; ×50. (p. 615)
9—*Kirkbya clarocarinata* Knight. Left valve; ×45. (p. 618)
10—*Amphissites robustus radiatus* McLaughlin, n. var. Right valve; ×25. (p. 618)
11, 12—*Amphissites congruens* Cooper. *11*, right valve ×20; *12*, left valve, ×50. (p. 617)
13, 14, 16—*Amphissites congruens* Cooper? *13*, left valve ×50; *14*, right valve ×35; *16*, left valve ×45. (pl 617)
15—*Polytylites wapanuckensis* (Harlton). Right valve ×35. (p. 618)
17—*Glyptopleura* aff. *G. coryelli* Harlton. Right valve ×20. (p. 616)
18—*Bairdia hoxbarensis* Harlton. Right valve ×20. (p. 615)
19, 20—*Bairdia oklahomaensis* Harlton. Right valves ×20. (p. 614)
21-23—*Healdia punctata* McLaughlin, n. sp. Left valves ×45. (p. 616)
24, 25—*Healdia unispinosa* McLaughlin, n. sp. Left valves ×50. (p. 617)
26, 27—*Cavellina* cf. *C. fittsi* Kellett. *26*, left valve ×25; *27*, right valve ×20. (p. 615)



McLaughlin, Pennsylvanian Microfauna from Colorado



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EXPLANATION OF PLATE 83

All specimens magnified 45× unless otherwise indicated.

FIGS. *1, 5—Polygnathodella ouachitensis* Harlton (p. 620)
2—Cavusgnathus flexa Ellison (p. 620)
3, 4, 6, 7—Cavusgnathus giganta Gunnell (p. 620)
8–11—Idiognathodus delicatus Gunnell. *9, 10,* ×50. (p. 619)
12–14—Idiognathodus magnificus Stauffer and Plummer. *12, 14,* ×40 (p. 619)

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A TROCHOCERATOID NAUTILOID FROM THE HENRYHOUSE SHALE (SILURIAN) OF OKLAHOMA

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ABSTRACT—A unique specimen is illustrated and described as a new species of *Leurotrochoceras* Foerste.

RECENTLY a new professional collector, Mr. J. Travis Stevens of Ada, Oklahoma, donated to the State University of Iowa four nautiloids from the Henryhouse shale of central southern Oklahoma. Insofar as we have been able to ascertain, no cephalopods have been described from that formation as delimited by Maxwell (1936, p. 133), though Reeds (1911, p. 262) lists "*Orthoceras* n. sp." as occurring in it. Three of the Henryhouse specimens now available to us are very poorly preserved. The largest of these is a moderate-sized cyrtoceracone, whereas the others are orthoceracones, one of which bears relatively small longitudinal ribs.

The fourth specimen in the collection under consideration is a coiled form that seems to be slightly trochoceratoid. It belongs in *Leurotrochoceras* Foerste (1930, p. 62) but does not appear to be referable to any of the three species that have been placed in that rare genus. We propose to name this new form in honor of its discoverer as follows:

LEUROTROCHOCERAS STEVENSI M. & C., n. sp.
Plate 84, figs. 1, 2

The single specimen on which this species is based is a well-preserved internal mold of about one and a half volutions of a more or less tarphyceraconic conch. It is not complete adapically or adorally, but its maximum diameter measures about 78 mm. The adoral fifth-volution of this holotype is non-septate and therefore represents body chamber, whereas the rest of it represents phragmocone. The conch is compressed and flattened laterally, broadly rounded dorsally, and more narrowly so ventrally. The whorls of at least the internal mold do not appear to be quite in contact. The adapical portion of the type specimen is only partially removed from the matrix, but it seems to be more or less subcircular in cross-section. However, during ontogenetic development the height of the conch increased more rapidly than the width, and near the junction of the phragmocone and the body chamber these two transverse measurements are about 25 mm. and 19 mm., respectively.

The holotype may have been slightly distorted during preservation, but its coiling does not appear to have been quite planispiral. That is, the adapical portion of the specimen seems to deviate slightly but distinctly from the median plane of the outer whorl and to be coiled sinistrally.

The umbilicus is large and was clearly perforate. Its diameter is equal to about half that of the specimen. On the adapical portion of the holotype, the umbilical shoulders are broadly rounded, but adorally they become more abrupt.

The surface of the internal mold bears numerous low rounded oblique ribs which curve apicad from the umbilical shoulders and form deep, narrowly rounded sinuses on the venter. These ribs are much more prominent on the adapical portion of the holotype than on the adoral part of it, but they can be discerned on at least all of the phragmocone.

The camerae are moderately short, and there are about 14 of them in the adoral half-volution of the phragmocone. Each mature suture forms a moderately high, rather narrowly rounded ventral saddle and on either side of it a broadly rounded asymmetrical lateral lobe and apparently a low rounded saddle on the umbilical shoulder. No trace of the siphuncle is vis-

ible, and breaks in the specimen show that the internal structures are probably not preserved.

Remarks.—This species resembles two of the three previously known representatives of the genus *Leurotrochoceras*: *L. aeneas* (Hall)—the genotype—and *L. compressum* Foerste of the Niagaran along the Mississippi River in eastern Iowa and northwestern Illinois, respectively. However, in rate of adoral expansion its conch is intermediate between these forms, and its camerae are distinctly longer. The other congeneric species, *L. paucoplanatum* Foerste of the same horizon and locality as *L. compressum* (the type section of the Port Byron dolomite), is not well known, but its conch is almost as wide as high. As in the genotype, the adapical portion of the conch of *L. stevensi* "is only faintly asymmetrical in location . . . [and] the coiling is sinistral." The fact that this form is closely related to Niagaran species, and no others, substantiates the belief that the formation which yielded it is Middle Silurian in age (see Amsden, 1951, p. 72).

Occurrence.—Henryhouse shale (39 ft. below top) in the valley of the South Fork of Jackfork Creek about 200 feet southwest of the mouth of an unnamed tributary, in the NE ¼ SW ¼ Sec. 4, T. 2 N., R. 6 E., some 10 miles west and a little north of Stonewall, Pontotoc County, Oklahoma.

Holotype.—State Univ. Iowa, 9813.

Addendum.—Since the above discussion was submitted for publication, Mr. Stevens has secured an additional representative of the new species from the same bed in the Henryhouse shale about a quarter of a mile southwest of the locality that yielded the holotype. This specimen (State Univ. Iowa, 1913) is much more nearly complete than the type. Its maximum diameter measures a little more than 100 mm., and the adoral half-volution of it represents body chamber. One side of the specimen, an internal mold, is removed from the matrix, and on it in the adoral half of the body chamber the umbilical wall bears four or five prominent rounded transversely elongate nodes which may possibly represent an internal structure of the conch or which may be adventitious. The preservation of this part of the specimen is not all that could be desired, but apparently both sides of it bear similar nodes.

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JOURNAL OF PALEONTOLOGY, VOL. 26, NO. 4, PP. 624–625, PL. 84, 2 TEXT FIGS., JULY 1952

TWO CEPHALOPODS FROM NEAR THE KINDERHOOK-OSAGE BOUNDARY IN MISSOURI

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ABSTRACT—Typical representatives of *Triboloceras* and *Munsteroceras* are illustrated and described from the Sedalia and the St. Joe limestones, respectively. The nautiloid is conspecific with forms that are abundant in the underlying Chouteau limestone, whereas the goniatite belongs in a species previously known from only the Fern Glen limestone of southwestern Illinois. It is concluded that these cephalopods, taken by themselves, seem to suggest that the middle Sedalia is upper Kinderhook and that part of the St. Joe is basal Osage.

WHILE we were preparing a study of the Kinderhook ammonoids of Missouri, Drs. Edward L. Clark and Thomas R. Beveridge of the Division of Geological Survey and Water Resources of that state sent to the State University of Iowa two Mississippian cephalopods which seem to be far more than ordinarily significant. That is, both came from formations of which the age has been questioned, and both belong in species believed to have considerable stratigraphic value.

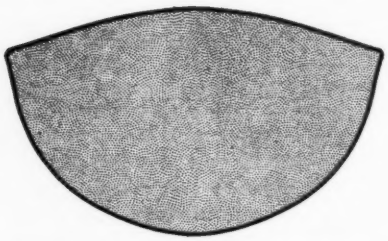

FIG. 1—*Triboloceras digonum semicirculare* M. & F. Cross section (restored), based on the adapical portion of the specimen represented by figure 3 on plate 84, ×2.

One of these specimens (pl. 84, fig. 3) is a nautiloid that was secured by Dr. Beveridge from the middle part of the Sedalia limestone in the M. K. & T. (Sweeney) quarry at Clifton City, in central Missouri. He has written us that it "is definitely from the Sedalia, for it is from beds well below those referred by some to the Burlington and by others to the uppermost Sedalia." Clearly it is referable to *Triboloceras digonum semicirculare* Miller and Furnish, which is of widespread occurrence in the underlying Chouteau limestone of Missouri and is also known from the Redwall limestone of Arizona and the Caballero formation of New Mexico. Furthermore, conspecific forms have been found in the Rockford limestone of Indiana, the Northview formation of Missouri, and equivalent beds in Illinois; and congeneric species have been recorded from Kentucky, western Europe, and European Soviet Russia. At least all of the American representatives of *Triboloceras* of which the age is definitely known came from the Lower Mississippian Kinderhook group or series, and therefore the occurrence of the genus in the Sedalia can be said to

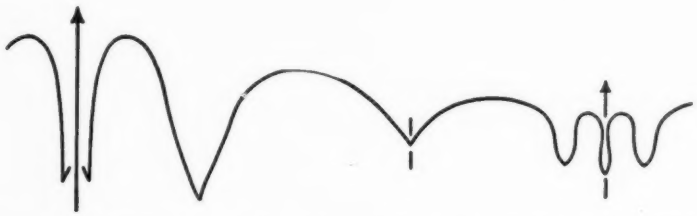

FIG. 2—*Munsteroceras pfefferae* (M. & W.). Diagrammatic representation of a complete suture, based on the specimen illustrated by figures 4–6 on plate 84, at a diameter of about 80 mm., ×1.

constitute further evidence for the current belief that all but the uppermost part of that formation is Kinderhook in age.

The goniatite under consideration (pl. 84, figs. 4–6) was obtained in 1939 by Dr. Clark from the "upper 3 feet of the middle St. Joe limestone" on the north side of Rock Creek in the $SW\frac{1}{4}NW\frac{1}{4}SW\frac{1}{4}$ Sec. 6, T. 22 N., R. 26 W., Barry County, southwestern Missouri. We have compared it directly with the specimen from the Fern Glen limestone of southwestern Illinois for which Miller and Werner (1942) proposed the specific name *Imitoceras pfefferae*. Both of these indivduals are slightly distorted, and in both it is difficult to ascertain the precise nature of the adapical portion of the ventral lobe of the sutures. Nevertheless, after very careful consideration, we have concluded that they cannot be differentiated specifically and that in each the ventral lobe is slightly but distinctly bifid, indicating that they belong in the genus *Munsteroceras*. The fact that the St. Joe specimen is conspecific with one from the Fern Glen, the only other representative of the species known, seems to us to support strongly the correlation of portions of these two formations. Inasmuch as the Fern Glen is now generally believed to be very early Osage in age, it follows that part of the St. Joe should also be regarded as representing the base of that group or series—the lower portion of the formation is believed to be Kinderhook in age.

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JOURNAL OF PALEONTOLOGY, VOL. 26, NO. 4, PP. 626–629, PL. 85, 1 TEXT FIG., JULY 1952

A NEW JURASSIC NAUTILOID SPECIES FROM MOROCCO

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ABSTRACT—A typical representative of *Paracenoceras* from north of Marrakech is illustrated and described, and the name *P. marocense* is proposed for it. The affinities of this form indicate that it is most probably Upper Jurassic in age.

DR. JEAN ROGER of the French national museum of natural history in Paris kindly sent us for study two nautiloids that M. Marcel Gigout of the Cherifian institute in Rabat had collected at M'tal, between Mazagan and Marrakech. They are of somewhat different size but are most probably conspecific and are clearly referable to *Paracenoceras* Spath. However, they do not seem to belong in any previously described species.

The age of the rock which yielded these specimens is somewhat uncertain, but Dr. Roger has written us that it is either Upper Jurassic or Lower Cretaceous. We have no information in regard to the associated fossils; but these two cephalopods, taken by themselves, can be said to indicate rather strongly that the containing strata are most probably Jurassic, for almost all of the congeneric forms known seem to come from that system. Furthermore, with few exceptions, they are from the Upper Jurassic.

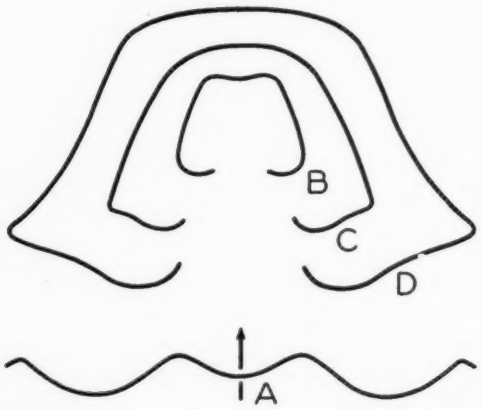

FIG. 1—*Paracenoceras marocense* M. & C., n. sp. Diagrammatic representations of a mature external suture (*A*); and cross-sections of the conch during early (*B*), typical (*C*), and late (*D*) maturity, all ×½. *A*, *C*, and *D* are based on the holotype; *B* on the paratype.

PARACENOCERAS MAROCENSE M. & C., n. sp.

Plate 85, figs. 1, 2

Both of the specimens on which this species is based are internal molds moderately well preserved in fine-grained light-colored limestone that is mottled reddish brown. Only the larger of them seems to have attained full maturity, and therefore it is being chosen as the holotype. This individual represents about half a volution of a conch that was at least 115 mm. in diameter. Although most of it portrays body chamber, the two adoral camerae of the phragmocone are retained. The paratype represents essentially the same portion of the conch of a smaller individual, and its maximum overall dimension is about 78 mm.

The conch is very thickly subdiscoidal in shape as it is wider than high, is flattened ventrally and laterally, and is impressed dorsally—the lateral zones are distinctly converged ventrad. During early maturity the conch is almost as high as wide and is retuse ventrally; but as full maturity is approached it becomes relatively wider and slightly but distinctly convex ventrally—that is, the median ventral groove becomes obsolete. At late maturity the dorsolateral portions of the apertural margins are flared. The shape of the cross-section of the conch at successive stages of ontogenetic development is elucidated by text-figure 1. Nevertheless, it should perhaps be stated that throughout maturity the lateral and ventral zones are almost flat, and ventrolaterally the conch is abruptly rounded.

The umbilicus is open and is moderate in size, but it becomes relatively larger where the apertural margins are flared. During early maturity its diameter is equal to about a fifth that of the specimen, but at the adoral end of the holotype it is nearer a third. The umbilical shoulders are rounded, and the umbilical walls are very steep. However, during late ontogenetic development, where the aperture is flared, the umbilical shoulders become very abrupt and the umbilical walls less precipitous. On the lateral and ventral zones of the paratype (but not the holotype) there are suggestions of increments of growth, which indicate that the conch bore a rounded ventral sinus.

As shown by text-figure 1A, each mature suture forms a rather shallow, broadly rounded ventral lobe and on either side of it a narrowly rounded ventrolateral saddle (which centers on the ventrolateral shoulder of the conch), and a shallow broadly rounded lateral lobe which extends to a relatively small narrowly rounded saddle that centers on the umbilical shoulder. There appears to be no material difference between the early mature sutures shown by the paratype and the fully mature ones of the holotype.

At the adapical end of the holotype, there can be seen a structure that probably represents the siphuncle, though it is very poorly preserved. It is located fairly close to the dorsum.

Remarks.—This form seems to be closely related to *Nautilus hexagonus* Sowerby of the Upper Jurassic of England and probably France (but not India as suggested by Sowerby in 1840, p. 329, pl. 23, fig. 4—see Spath, 1927, p. 31). That species, which is the genotype of *Paracenoceras* Spath, was established in 1826, and the only available description and illustrations of the original type specimen leave much to be desired. Nevertheless, it is clear that in *P. hexagonum* and in *P. marocense* the general physiognomy and the cross-section of the conch are about the same, and in both the venter is distinctly concave during early but not full maturity. Furthermore, the size of the umbilicus and the shape of the sutures is essentially the same in these two species. However, they seem to differ in that at full maturity the aperture of the African form is considerably flared, whereas that of the European one apparently is not—Foord (1891, p. 236) had a representative of the latter species in which the "greatest diameter [measured] 15 inches," and if its aperture was flared, he failed to mention it. Spath (1927, p. 30) states that Foord had included in "*N.*" *hexagonus* examples of *P. arduennense* (d'Orbigny) and *P. rollieri* (Loesch) of the Upper Jurassic of France and Switzerland, respectively; but in both of those forms the venter is not concave during early maturity.

Several species are known from the Jurassic of India that are reminiscent of the Moroccan one we are studying (see Spath, 1927, pp. 26–33). However, as in the genotype, most of them do not seem to have a strongly flared aperture. *P. hexagonoides* Spath of the Tithonian of Cutch appears to be somewhat flared aperturally, but it differs from *P. marocense* in that its venter is concave during relatively late growth stages. Spath (1927, p. 29) mentions a "similar depressed and sulcate" form from the Kimmeridgian? of British Somaliland; and he (Spath, 1935, pp. 224–225) has described a congeneric species from the "Bathonian?" of that country.

Krenkel (1910, p. 220, pl. 22, fig. 16; pl. 23, figs. 1, 2) illustrated and described as *Nautilus sattleri* a typical representative of *Paracenoceras* from Tanganyika, and it is somewhat similar to *P. marocense* but has a relatively broad conch. Although he believed the age of his specimen to be Lower Cretaceous, Zwierzycki (1914, p. 87) has shown that it is upper Kimmeridgian. Furthermore, Zwierzycki, like Spath (1927, p. 22), stated unqualifiedly that *Paracenoceras* is limited to the Jurassic, and he thought it occurred in only the upper portion of that system. However, Spath, as just mentioned, has recorded a representative from the "Bathonian?"; and, furthermore, he (Spath, 1927, p. 25) seems to refer to this genus *Nautilus rhodani* Roux of the Albian near Geneva [see Pictet, 1848], which we also would tentatively place in it. At Mombasa the genus occurs in the Upper Jurassic (see Dacqué, 1910, p. 3), and early in 1952 Bernhard Kummel wrote that he is de-

scribing a species from the Bajocian of Alaska.

Sinuous transverse ribs are present on the lateral zones of two of the species that have been referred to this genus: *Nautilus jumarensis* Waagen of the Upper Jurassic of India and *P. costatum* Scott of the same general horizon in Ethiopia. As noted by Scott (1943, p. 88), it "is possible that a new genus should be created for [these forms]."

Several genera are listed by Spath (1927, p. 22) as being closely related to *Paracenoceras*. In the genotype of *Tithonoceras* Retowski, *T. zitteli* Retowski of the Upper Jurassic of Crimea, the conch is strongly compressed, the ventral portions of the lateral zones are concave, and the ventrolateral shoulders are prominent and, though rounded, are more or less carinate. The type species of *Somalinautilus* Spath, *Nautilus antiquus* Dacqué (1910, p. 42) of the Upper Jurassic of Ethiopia, also bears ventrolateral ridges, which, however, are relatively small and are subangular. *Nautilus saxbii* Morris of the Cretaceous of Britain and France is the genotype of *Heminautilus* Spath, and it has a discus-shaped conch and strongly sinuous sutures. *Aulaconautilus* Spath is typified by *Nautilus sexcarinatus* Pictet of the Upper Jurassic of France, in which the venter is longitudinally costate, the umbilicus is small, and the sutures are strongly sinuous. The genotype of *Carinonautilus* Spengler, *C. ariyalurensis* Spengler of the Cretaceous of southern India, has a discus-shaped conch which at full maturity bears rounded ventrolateral keels.

Occurrence.—Lentil of reef limestone in an Upper Jurassic? conglomerate at M'tal, Morocco (see Gigout, 1950, p. 1250).

Types.—Institut Chérifien, Rabat.

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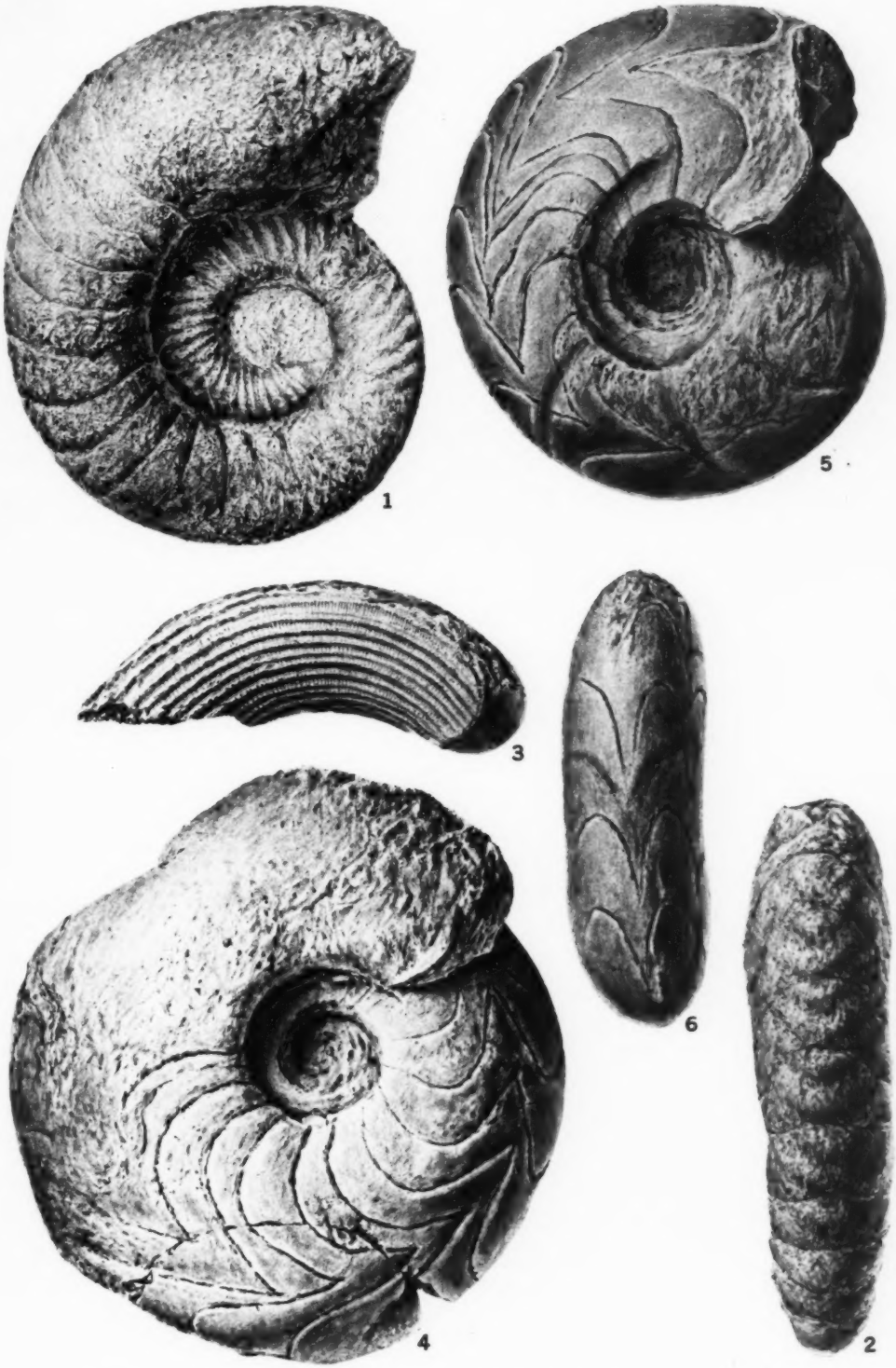
EXPLANATION OF PLATE 84

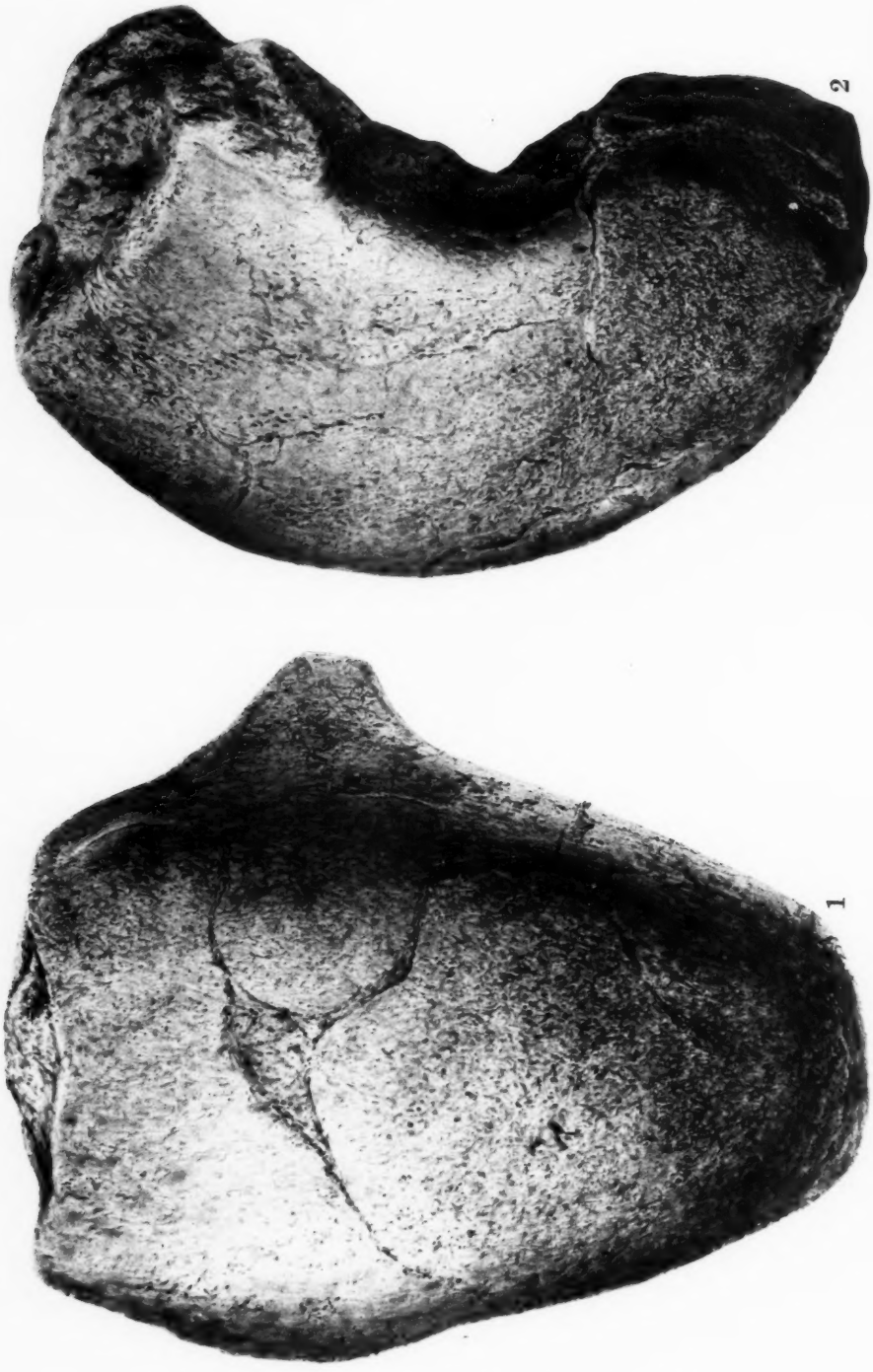
FIGS. *1, 2*—*Leurotrochoceras stevensi* M. & C., n. sp. Two views of the holotype, from the Henryhouse shale along the South Fork of Jackfork Creek some 10 miles west and a little north of Stonewall, Oklahoma, ×1. (p. 622)

3—*Triboloceras digonum semicirculare* M. & F. Lateral view of a typical specimen from the Sedalia limestone at Clifton City, Missouri, ×1. (p. 624)

4–6—*Munsteroceras pfefferae* (M. & W.). Lateral view (fig. 4) of a mature individual, and two views (figs. 5, 6) of all but the adoral two-thirds of the outer volution of the same specimen, from the St. Joe limestone along Rock Creek in Sec. 6, T. 22 N., R. 26 W., Barry County, Missouri, all ×1. (p. 625)



Miller and Collinson, Silurian and Mississippian Cephalopods



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EXPLANATION OF PLATE 85

FIGS. *1, 2*—*Paracenoceras marocense* M. & C., n. sp. Ventral and lateral views of the holotype, from the Upper Jurassic? of M'tal, between Mazagan and Marrakech, Morocco, ×1. (p. 626)

JOURNAL OF PALEONTOLOGY, VOL. 26, NO. 4, PP. 630–639, 3 TEXT FIGS., JULY 1952

PHYLOGENY AND TAXONOMY OF FOSSIL HORSESHOE CRABS

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ABSTRACT—Fossil Xiphosura are known from all geological systems from the Cambrian onward. A distinct trend of development, particularly from the Silurian to Recent time, is demonstrated. The early xiphosuran representatives were probably closely related to the Merostomoidea and the Trilobita. The classification of the Xiphosura is discussed and several new families and genera are proposed.

INTRODUCTION

THE horseshoe or king crabs are perhaps the most striking "living fossils" of the present seas. Five species, confined to the waters along the east coast of North America and the southeast and east coasts of Asia, are the only survivors of a peculiar arthropod stock of which fossil representatives are known from all geological systems from the Cambrian onward.

The recent horseshoe crabs, or Xiphosura, belong to the genera *Limulus* (=*Xiphosura*) *Tachypleus* and *Carcinoscorpius*. The American species *Limulus polyphemus* (Linnaeus) is the largest, measuring up to about 60 cm. in length. The recent forms are typical bottom dwellers, digging in the mud and sand of shallow marine waters near the shore. The Asiatic *Carcinoscorpius rotundicaudata* (Latreille) is able, however, also to migrate up rivers into perfectly fresh water.

As suggested by the name, the horseshoe crabs were in former days considered true crustaceans. In the early part of the last century, however, Strauss-Dürkheim (1829) suggested affinities with the Arachnida, and this view was generally adopted after Ray Lancaster published his paper: "*Limulus* an Arachnid" (1881).

The fossil Xiphosura early attracted the attention of scientists. Beautifully preserved specimens of *Limulus* very similar to Recent ones were found in the Jurassic lithographic shales of Germany. Related species were obtained from other Mesozoic sediments and soon more primitive forms were discovered in late and early Paleozoic beds. More recently very early representatives of the Xiphosura have been described from America.

In the following, an attempt is made to trace backwards the development of the xiphosuran stock. As shown below, it appears possible to distinguish a fairly continuous line of development back to the Silurian, and still older related forms occur in the Ordovician and Cambrian. The possible affinities between the earliest Xiphosura and the various members of the Trilobitomorpha are also considered.

POST-PALEOZOIC LIMULINA

From the Miocene lignite beds of Germany, Zinken (Böhm 1905) described a very large limulid (fig. 1n) resembling considerably the recent species of *Tachypleus* and tentatively referred here to that genus.

Only one species, *Mesolimulus* (?) *syriacus* (H. Woodward 1879), has been described from the Cretaceous. It is known from only one imperfectly preserved specimen (fig. 1m).

The new genus *Mesolimulus*, based on the well-known *M. walchi* (Desmarest) (fig. 1l), is characteristic of the Jurassic. Compared with Recent forms, it shows primitive features particularly in having distinct dorsal furrows. A furrow along the inner margin of the genal angles may also be a primitive character. As pointed out by Ivanov (1933), this furrow conforms with the border between the pleural portions of the 6th and 8th segments. A fragment of a very large species, "*Limulus*" *nathorsti* Jackson (1906) from the Lias of Scania, Sweden, may also belong to *Mesolimulus*. Another Jurassic species, described as *Limulus woodwardi* by Watson (1909), from England possibly belongs to a different genus.

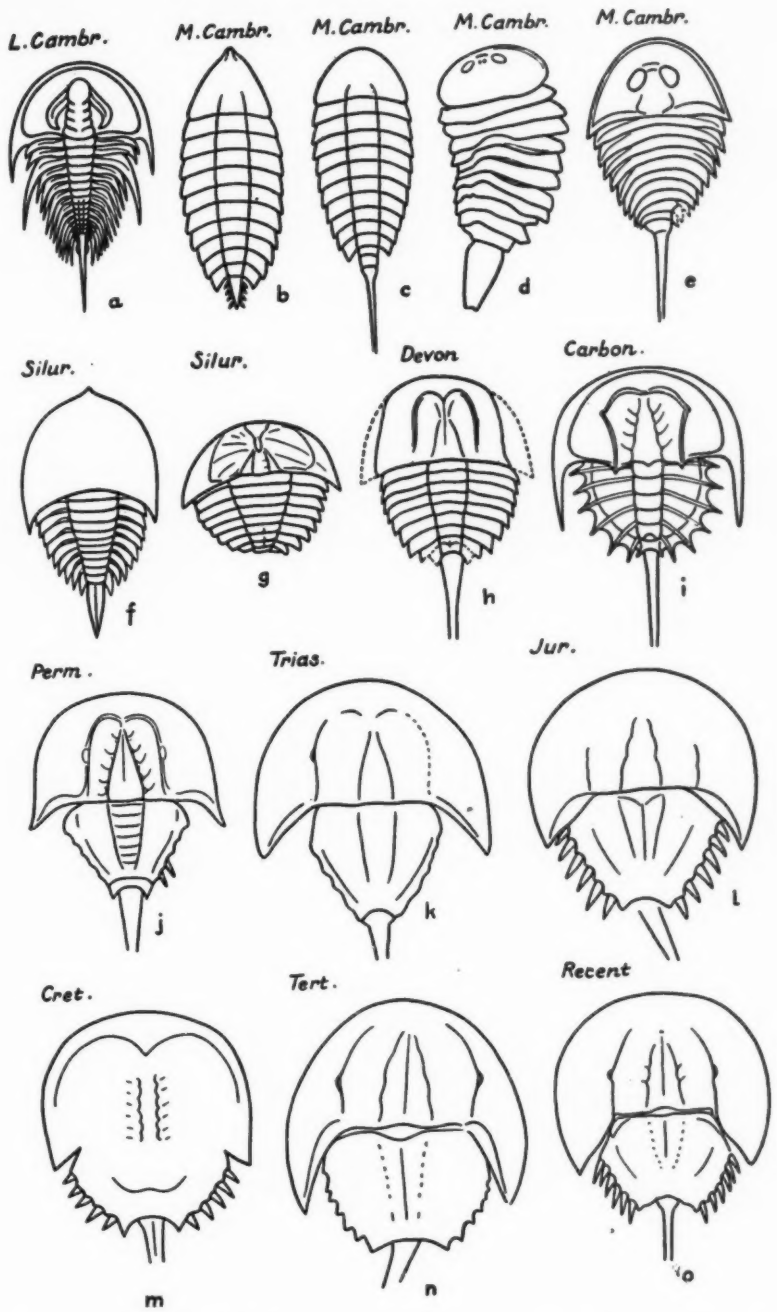


FIG. 1—Xiphosura and early relatives.
a. = Trilobita, *Olenellus thompsoni* (Hall) (Størmer 1944); *b.* = Merostomoidea, *Leanchoilia superlata* Walcott (Størmer 1944); *c.* = Merostomoidea, *Emeraldella brocki* Walcott (1912); *d.* = Aglaspida, *Strabops thacheri* Beecher (1901); *e.* = Aglaspida, *Glypharthrus thomasi* (Walter); *f.* = Synziphosurina, *Weinbergina opitzi* (R. and E. Richter 1929); *g.* = Synziphosurina, *Neolimulus falcatus* Woodward (1868); *h.–o.* = Limulina; *h.* = *Neobelinuropsis rossicus* (Chernychew 1933); *i.* = *Euproöps thompsoni* Raymond (1944); *j.* = *Palaeolimulus avitus* Dunbar, reconstruction; *k.* = *Limulitella bronni* Schimper (after photograph of holotype); *l.* = *Mesolimulus walchi* (Desmarest) (Kirchner 1926); *m.* = *Mesolimulus* (?) *syriacus* (Woodward 1879); *n.* = *Tachypleus decheni* (Zincken) (Böhm 1905); *o.* = *Tachypleus gigas* Müller (from Gerhardt 1932 after Gerstäcker).

Several horseshoe crabs are known from the Upper, Middle and Lower Triassic. Most of them seem to belong to the genus renamed *Limulitella* (fig. 1k) which is related to *Mesolimulus* but has more outwardly directed genal angles and a narrower abdomen, features typical of still older forms. The late Triassic species *Limulitella* (?) *vicentis* (Bleicher 1897) and the Rhaetic *L. liaso-keuperensis* (Braun 1860) have a median keel on the abdominal axis as in Upper Jurassic *Mesolimulus*. *Psammolimulus* Lange (1923) of the Lower Triassic is not well known, but seems to resemble the more common *Limulitella*.

As shown in figs 1k to n, the Mesozoic and Cenozoic horseshoe crabs are closely related and rather similar to Recent forms. A gradual change from the Triassic onward is shown by the obliteration of the dorsal furrows and the backward growth of the genal angles, the latter accompanied by the backward migration of the marginal spines of the abdomen. A general increase in size is also rather significant.

PALEOZOIC LIMULINA

This line of development may be traced backward through the Paleozoic systems. The small *Paleolimulus avitus* Dunbar, of the Permian of Kansas (fig. 1j), is well known from the detailed descriptions by Dunbar (1923) and Raymond (1944). The appendages are preserved, and they are surprisingly similar to those in Recent forms. *Paleolimulus* has many features in common with the Mesozoic genera, but the occipital ridges meet in front, the genal angles are more outwardly directed and the well differentiated axis of the abdomen is primitively annulated. Peculiar to it is a free segment in front of the telson. This genus is known also from the Carboniferous of the Donetz basin in Russia (Chernychew 1933) and a prosoma possibly belonging to the same genus was described from the Upper Devonian of New York by Beecher (1902) (cf. Dunbar 1923).

Several small forms belonging to the superfamilies Euproöpacea and Belinuracea are characteristic of the Carboniferous and Permian. The Euproöpacea (fig. 1i) differ from the later horseshoe crabs by their more distinct segmentation both of the axis and pleural areas of the abdomen. Some of the Euproöpacea, particularly the Liomesaspidae Raymond (1944), represent offshoots from the general phylogenetic line of development.

The Belinuracea represent a more primitive stage as they have the abdominal shield divided into a number of free movable tergites. The Devonian species, *Neobelinuropsis rossicus* (Chernychew 1933), has a characteristic limulid prosoma with the typical cardiac lobe (fig. 1h). Only the two last segments of the abdomen seem to be anchylosed.

The Silurian species, *Neolimulus falcatus* Woodward (1868), is of particular interest (fig. 1g and 3a,b). Through the courtesy of Dr. C. J. Stubblefield and Mr. Baker of the British Museum, photographs have been taken of the holotype (fig. 2a,b). It has the occipital ridges of a typical limulid and the abdomen is not much different from that of the Devonian and Carboniferous Belinuracea. Partly because of its great age, this genus has been referred to the contemporaneous Synziphosurina and synziphosuran characters may be recognized in the primitive segmentation of the interophthalmic region and in the development of the cardiac lobe, features found in *Bunodes* and *Bunaia* (Størmer 1934 b). Nevertheless *Neolimulus* closely approaches the earliest Limulina or true horseshoe crabs.

As shown in figs. 1g to o, a fairly continuous line of development may be traced through the genera *Neolimulus—Neobelinuropsis—Paleolimulus—Limulitella—Mesolimulus—Tachypleus*, ranging from the Silurian to Recent time.

SYNZIPHOSURINA

The Silurian and Lower Devonian Xiphosurida belong to the Suborder Synziphosurina, a rather heterogeneous group comprising mostly blind forms. A cardiac lobe resembling that of later forms, is indicated in *Bunodes* and *Bunaia* (Størmer 1934 b), but it is absent in others, i.e. in *Pseudoniscus* (fig. 1f). A primitive feature of the Synziphosurina is the interophthalmic segmentation demonstrated in several genera. At least some of the Synziphosurina probably repre-

sent offshoots from the main line of development.

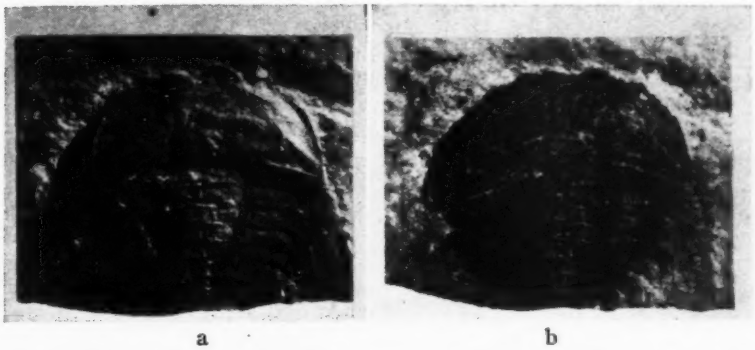
AGLASPIDA

Until recently Xiphosura have been unknown in the Ordovician but Dr. Kenneth E. Caster has informed me that he has found a specimen in the Upper Ordovician near Cincinnati, Ohio. This belongs to the Aglaspidae and thus is a late representative of the order Aglaspida which is otherwise confined to the Cambrian.

Knowledge of the Aglaspida has been considerably increased by Raasch (1939). Aglaspida differ in several features from the later Xiphosura, they evidently belong to the same evolutionary stock. As suggested in figure 2, the group probably branched off from the main line leading to *Neolimulus* and the other horseshoe crabs.

RELATIONS TO EURYPTERIDS

The excellently preserved Silurian eurypterids of North America and Europe show that the Eurypterida are closely related to the Xiphosura and these are joined in a common class, the Merostomata. The Middle Cambrian aglaspid *Strabops*



a b

FIG. 2—*Neolimulus falcatus* Woodward. *a*, holotype, Upper Silurian Lesmahago, Lanarkshire, England; *b*., photographed in alcohol, specimen 44122, British Museum (Natural History).

This order is similar to the Synziphosurina in having a semielliptical prosoma with a multijointed abdomen terminating in a lanceolate telson (figs. 1d,e). The abdomen is comparatively larger and has a greater number of movable joints (11) than in the Synziphosurina. In the Middle Cambrian genus *Beckwithia* Resser (1931), the last joints are anchylosed. In the Aglaspida, the prosoma has well-developed eyes and when a cardiac lobe is present, it is considerably broader than in the later Xiphosura. The postventral plates supporting the powerful telson are typical of the group. The xiphosuran nature of the Aglaspida is confirmed by the presence of six pairs of prosomal appendages of which the first evidently is developed as chelicerae (but with 4 instead of 3 joints). The walking legs of the abdomen, however, are not strongly reduced as in more recent representatives of the Xiphosura.

Although the Cambrian and Ordovician (fig. 1d) has been regarded by some authors as a true eurypterid.

The Eurypterida also are related to the Arachnida, and the Merostomata, together with the Arachnida, constitute a subphylum, the Chelicerata (fig. 3).

RELATIONS TO TRILOBITES

The affinities with the Trilobita and other early Paleozoic arthropods have been subject to much discussion. Some of Walcott's (1912) beautifully preserved arthropods from the Middle Cambrian Burgess shale of British Columbia are very like the Aglaspida (figs. 1b, c). Fortunately the appendages are known to a certain extent. The cephalic or prosomal appendages of *Leanchoilia* and *Emeraldella* suggest the presence of only 4 postoral appendages instead of 6, as in the Aglaspida and other Xiphosura. This implies that the cephalon consists of only 4 postoral segments, instead of the 6 that are present in the primitive Xiphosura. The

early embryo of the horseshoe crab, however, shows 4 primary segments only. The Burgess shale forms have preoral antennae which are unknown in the Xiphosura. This difference, however, is not necessarily important because rudiments of antenna-glomeruli are distinguishable in the brain of the horseshoe crab (Størmer, 1944).

The Middle Cambrian Burgess shale arthropods have very characteristic biramous appendages, quite similar to those of

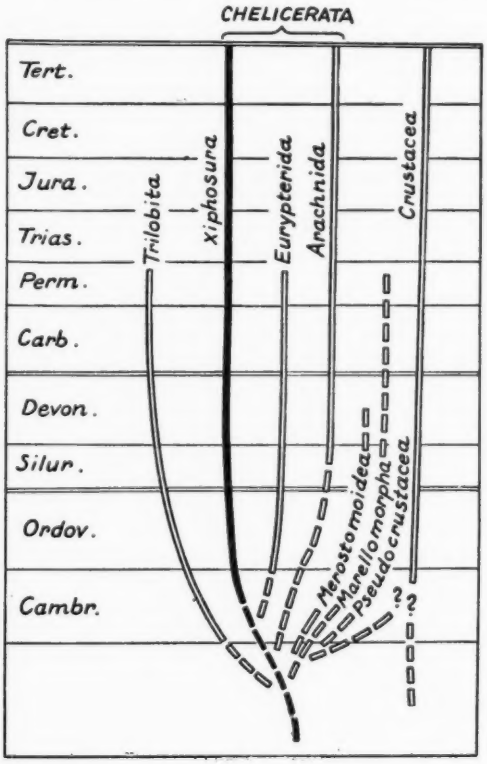


FIG. 3—The descent of the Xiphosura.

the trilobites, which are important features linking the Trilobita with the previously mentioned groups (fig. 3). Support for the assumption of relationship between the Trilobita and the Chelicerata is furnished by the structure of the abdominal gill-appendages of the horseshoe crab and by the more or less modified trilobite-like appendages of various arachnids. Lower Cambrian olenellid trilobites (fig. 1a) are not very different from the Cambrian Aglaspida (fig. 1e). The dorsal spine of these primitive trilobites may be homologized with the telson of the Xiphosura (Ivanov, 1933; Størmer, 1944).

The fossil material available at present strongly suggests a relationship between the Chelicerata and the Trilobitomorpha which comprises the other groups mentioned above. Thus it seems possible to trace the ancestry of the horseshoe crab backward well into the Cambrian, and to the first appearance of well-preserved arthropods.

RELATIONS TO CRUSTACEANS

A problem yet unsolved is the relation between the Crustacea and the Trilobitomorpha. Several of the Burgess shale arthropods have a distinct crustacean appearance and at the same time typical trilobitan appendages. Whether this means that both the Trilobitomorpha and the Crustacea had a common ancestor, or that the crustacean-like forms (Pseudocrustacea) were members of the Trilobitomorpha, their crustacean appearance being only a matter of homeomorphy, is still an open question. The apparent lack of any rudiment of a typical trilobitan appendage among the numerous types of crustacean appendages (cf. Størmer, 1944, 1951) seems to favor the latter alternative.

CLASSIFICATION AND NOMENCLATURE

For the Treatise on Invertebrate Paleontology being prepared under the editorship of R. C. Moore, the present author is treating the genera, families and higher taxonomic groups of the Merostomata. In this work, it has become apparent that some new groups must be established and that certain generic names are preoccupied and must be changed.

XIPHOSURA VS. LIMULUS

Confusion has arisen regarding the names *Xiphosura* and *Limulus* which are the most familiar names attached to this group. The first has been applied chiefly to the major group and the latter to the best known recent species, *Limulus polyphemus* (Linnaeus).

The genus *Limulus* was erected by Müller (1785) with the species *Monoculus polyphemus* Linnaeus as the type species.

The generic name *Limulus* was generally accepted until Pocock (1902) pointed out that Gronovius in 1764 had introduced the name *Xiphosura* for this genus. The new generic names of Gronovius were mentioned by Meuschen (1788) in his index to Gronovius' paper. Because binary nomenclature was not consistently used in these early works, the new names were regarded as invalid by the International Commission of Zoological nomenclature (Bull. Zool. Nom. *4*, p. 311, 1950) and the name *Limulus* Müller was placed on the "Official List of Generic Names in Zoology" (Opinion 104).

Meanwhile at its 12th Meeting in Paris, in 1948, the Commission decided that certain genera proposed by Brünnich (1771) were valid. This involves Brünnich's use of the generic name *Xiphosura* earlier than the introduction of *Limulus* by Müller. At the meeting, it was suggested that the Commission should decide whether the name *Limulus* should be validated or cancelled. It was pointed out that it would be advantageous to maintain *Limulus*, first because it is so well-known, and second because the name Xiphosura had long been used (since Latreille 1802) as the name of the Subclass (Order) and it would be objectionable to have the same name for both the genus and and the subclass.

The present author has sent to the International Commission an application for maintaining the generic name *Limulus*.

In anticipation of favorable action by the Commission, the name *Xiphosura* and derivations are used here provisionally for the Subclass and Order and the name *Limulus* and derivations are maintained for the genus, subfamily, family and superfamily.

ORDERS

The Family Aglaspidae was erected by Miller (1877) but later Walcott (1912) and Raasch (1939) extended the name to comprise an order of the Xiphosura. Among the generic names introduced by Raasch, *Cyclopina* is preoccupied (Neave 1939–40) and will be replaced by him.

In a previous paper the present author (Størmer 1944) divided the Xiphosura into three orders, the Aglaspida, Synziphosura and Limulida. More recent studies, however, indicate that the two latter groups should be combined into a single order, the Xiphosurida Latreille 1802, because of the close connection between the first group and early members of the Belinuracea in the second.

HEMIASPIS VS. LIMULOIDES

The generic name *Hemiaspis* Woodward 1865 is preoccupied (Neave 1939–40), and, therefore, a junior homonym. *Limuloides*, published as a *nomen nudum* by Salter in 1857 was quoted, however, by Woodward as a synonym and thus inadvertently validated nomenclaturally. *Limuloides* Salter in Woodward 1865 is the proper name of the genus. Its type is *Hemiaspis limuloides* Woodward (1865), the original monotypic species. The family name Hemiaspidae Zittel 1885 must give place to the new name Limuloididae.

SUBORDER LIMULINA

The classification of the Suborder Limulina has recently been revised by Raymond (1944). He divided it into three superfamilies to which he gave the names Belinuracea, Euproöpacea and Limulacea.

Belinuracea.—Raymond laid considerable stress on the course of the posterior branches of the ophthalmic ridges in Limulina. Some species of *Belinurus* Koenig 1820 were removed from that genus by him and named *Koenigiella* with *Belinurus reginae* Baily 1863 as the type species. These were said to be characterized by the parallel posterior branches of the ophthalmic ridges. It seems difficult, however, in all cases to rely on this character. The type specimen of *Belinurus bellulus* Woodward (1866–78 pl. 31, fig. 3a) has in fact parallel ridges which are inconsistent with such a division. The triangular abdomen of *Koenigiella* also seems hardly sufficient to justify its separation. Although the very comprehensive genus *Belinurus* probably should be subdivided when more extensive knowledge is obtained, it is difficult at present to maintain *Koenigiella* as a separate genus.

Euproöpacea.—The Superfamily Euproöpacea comprises at least three families, the Euproöpidae Eller 1938, Liomesaspidae Raymond 1944, and Elleridae Raymond 1944. Raymond pointed out the lack of dorsal furrows and the absence of lateral

spines on the abdomen in the Liomesaspidae. The genus *Liomesaspis* Raymond 1944 certainly represents a separate family, but the prominent and bulbous cardiac lobe seems to be more significant. Also, it lacks genal spines in the adult, marginal spines and raised pleural ridges on the abdomen, and has a high boss on the posterior segment of the axis. If the bulbous cardiac lobe is included in the diagnosis of the family, *Pringlia* Raymond 1944, included by that author in the Liomesaspidae, belongs to the Euproöpidae. The imperfectly known *Prolimulus* Fritsch 1899 may, because of its well rounded prosoma and abdomen, belong to the Liomesaspidae.

The family Elleridae consists of one genus, *Elleria* Raymond, based on a single abdomen described by Eller (1938) as *Euproöps morani*.

Another abdominal shield, for which the generic name *Kiæria* was proposed (Størmer 1934a), is of more uncertain taxonomic position. This large form from the Downtonian has a broad posterior indentation in the abdominal shield suggesting the occurrence of free abdominal segments behind it. The genus *Kiæria* evidently belongs to a separate family.

Family KIÆRIDAE Størmer n. fam.

Limulina (?) of large size, abdominal shield with axial furrows, segmentation and broad posterior indentation suggesting free segments in front of the telson (?). One genus, one species: *Kiæria limuloides* Størmer 1934.

Limulacea.—The family Limulidae, erected by Zittel (1885) and raised to a superfamily by Raymond (1944), embraces the real horseshoe crabs ranging from early Paleozoic representatives to Recent forms. Raymond pointed to the parallel posterior branches of the ophthalmic ridges and the trapezoidal abdomen with movable marginal spines as the major distinguishing characteristics.

RECENT LIMULACEA

From a paleontologist's point of view the taxonomic division of the recent limulids may seem to have been carried a little too far. The recent species characterize three genera: *Limulus* Müller 1785, *Tachypleus* Leach 1819, and *Carcinoscorpius* Pocock 1902, the first belonging to the subfamily Limulinae Pocock 1902, the others to the Tachypleinae Pocock 1902.

Unfortunately, the chief diagnostic characters of the Recent forms are confined to the inner branches of the bifurcated abdominal appendages. Because these appendages are practically unknown in the fossil forms, such characters are not very useful to paleontologists. Comparisons of Recent and fossil forms must be made chiefly on the structure of the dorsal shields and in this respect the Limulinae are mainly characterized by their more vaulted prosoma and less hexagonal abdomen with prominent posterior prolongations and lateral spines decreasing in length backwards, whereas the Tachypleinae have a less vaulted prosoma and more hexagonal abdomen with less prominent posterior prolongations and movable spines not decreasing in length backwards.

FOSSIL LIMULACEA

It is not possible or desirable to attempt such a detailed taxonomic subdivision of the fossil forms as has been made for the Recent ones, but it seems necessary to introduce some new genera for Mesozoic species generally referred to the old genus *Limulus* Müller.

Paleolimulus Dunbar 1923, the earliest member of the Limulacea, is unique, particularly because of the presence of a movable segment in front of the telson, certain "ancient" characteristics such as the meeting of the ophthalmic ridges in front, and the distinct annulation of the abdominal axis. This genus probably originated in the Carboniferous or possibly in the Devonian.

Several representatives of the Limulacea are known from the Triassic and Jurassic, one species occurs in the Cretaceous and another in the Tertiary, most of which have been referred to *Limulus*. The descriptions of Mesozoic species, however, are often unsatisfactory because of the confused preservation of the dorsal and ventral surfaces (cf. Kirchner, 1926).

Schimper (1850) described *Limulites* from the Triassic of Alsace with *L. bronni* (later described by Bill 1914) as the genotype. The name *Limulites* was chosen to indicate that relations with Recent forms were not completely known, but unfortunately, it is

preoccupied, as Krüger (1823) had used this "broad-sense" name for *Limulus polyphemus* and other species (Neave, 1939–40).

Another Triassic genus, *Psammolimulus*, was introduced by Lange (1923). The single specimen described is not well preserved and the interpretations of its structures have varied (Schlüter and Schmidt, 1927; Schmidt, 1928).

The remaining species have been referred to *Limulus*. I have studied most of the published descriptions and illustrations of the Mesozoic Limulacea and have also, through the courtesy of Madame S. Gilet in Strassbourg, received a photograph of the type specimens of *Limulites bronni*. From these, it seems possible to make a major taxonomic division of the Mesozoic limulids. This involves the introduction of two new generic names, one to replace the preoccupied name *Limulites* of Schimper. Future research may necessitate the recognition of additional genera.

From the Triassic to Recent time, as mentioned above, certain tendencies in the general phylogenetic development of the dorsal skeleton of the Limulacea are apparent. The axial furrows gradually become more obsolete and a keeled axis becomes characteristic of the later forms. The genal angles of the prosoma are directed outwards in the earliest forms and gradually become more prolonged posteriorly. In the earlier forms, the movable marginal spines are more equally divided between the anterior and posterior halves of the abdominal shield.

The following new names are introduced:

Genus LIMULITELLA Størmer nom. nov.
Text figure 1k

LIMULITES SCHIMPER 1850

Type species: Limulites bronni Schimper. Lower Triassic, Alsace.

Mesolimulidae with postmedian margin of genal angle forming an angle with anterolateral margin of narrow subtriangular abdomen, a median keel may occur on axis.

The following other species seem to belong to this genus: *Limulus henkeli* Fritsch (1906), Lower Triassic; *Limulus vicensis* Bleicher (1897), Upper Triassic; and *Limulus liaso-keuperinus* Braun (1860) Rhaetic. I have not seen Braun's description, but according to Stromer v. Reichenbach (1907) *L. liaso-keuperinus* is much like *L. vicensis* Bleicher. Both have keeled axes and thus are transitional to the Jurassic genus proposed below. The small species, *Limulus sandbergeri* Kirchner (1923), *Limulus priscus* Münster (1843) and *Limulus agnostus* Meyer MS (1838) are probably larval forms, possibly belonging to *Limulitella*. Triassic Limulacea have been recorded also from Virginia and North Carolina (Emmons, 1856).

Genus MESOLIMULUS Størmer, n. gen.
Text figure 1l

Type species: Limulus walchi Desmarest 1822. Upper Jurassic, Germany.

Mesolimulidae with postmedian margin of genal angle not forming angle with anterolateral margin of broad abdomen.

From the Jurassic lithographic shale of Solenhofen in Germany, Münster (1838 a, b) described six species in addition to the genotype. Whether these are valid species or merely individual variations and differences of sex, a more careful study of the original material might decide. *Limulus woodwardi* Watson (1909) from the Jurassic of England differs considerably from the genotype of *Mesolimulus* and may belong to another genus. *Limulus nathorsti* Jackson (1906) from Scania, Sweden, is too incompletely known to warrant closer determination. The Cretaceous *Limulus syriacus* Woodward (1879) from Lebanon (fig. 1m) has a short abdomen with possibly only five movable spines. At present, the inclusion of this species in *Mesolimulus* is questionable.

The Tertiary *Limulus decheni* Zinken 1862 (Böhm, 1905) (fig. 1n) has much in common with the Recent species. Both the more backwardly prolonged genal angles and the posterior position of the movable marginal spines are characteristic of the Recent forms. Because of the broad posterior indentation, the Tertiary species seems to belong to the subfamily Tachypleinae. It is not quite like either *Tachypleina* or the closely related *Carcinoscorpius*, but provisionally the species may be referred to the former genus.

In the superfamily Limulacea, Raymond (1944) included the two families Paleolimuli-

dae Raymond 1944 and Limulidae Zittel 1885. It seems natural to restrict the Limulidae to the two subfamilies. Limulinae and Tachypleinae. For the Mesozoic genera that have been described, a new family is introduced.

Family MESOLIMULIDAE Størmer, n. fam.

Limulacea of small to moderate size, prosoma with ophthalmic ridges not meeting in front of cardiac lobe, genal angles moderately prolonged backwards, axial furrows distinct, no distinct annulations of abdominal axis, first pair of marginal spines within anterior third of abdomen.

This family includes the following genera: *Mesolimulus* n. gen., *Psammolimulus* Lange and *Limulitella* nom. nov.

CLASSIFICATION

The following classification is suggested for the Subclass Xiphosura Latreille 1802:

Order Aglaspida Walcott 1911.
- Family Aglaspidae Miller 1877.
  - Genera: *Aglaspis* Hall, *Aglaspella* Raasch, *Glypharthrus* Raasch, *Aglaspoides* Raasch, *U-arthrus* Raasch, *Cyclopidella* Raasch, *Craspedops* Raasch, *Setaspis* Raasch, *Strabops* Beecher.
- Family Beckwithidae Raasch 1939.
  - Genus: *Beckwithia* Resser.

Order Xiphosurida Latreille 1802.
- Suborder Synziphosurina Packard 1886.
  - Family Limuloididae Størmer, n. name.
    - Genus: *Limuloides* Salter in Woodward 1865.
  - Family Bunodidae Packard 1886.
    - Genera: *Bunodes* Eichwald, *Bunaia* Clarke, ? *Bembicosoma* Laurie.
  - Family Neolimulidae Packard 1886.
    - Genus: *Neolimulus* Woodward.
  - Family Pseudoniscidae Packard 1886.
    - Genera: *Pseudoniscus* Nieszkowski, ? *Cyamocephalus* Currie, ? *Bunodella* Matthew.
  - Family Weinberginidae R. and E. Richter 1929.
    - Genus: *Weinbergina* R. and E. Richter.
  - Unclassified:
    - Genus: *Belinuropsis* Matthew.
- Suborder Limulina R. and E. Richter 1929.
  - Superfamily Belinuracea Raymond 1944.
    - Family Belinuridae Packard 1886.
      - Genera: *Belinurus* Koenig, *Neobelinuropsis* Eller, *Protolimulus* Packard.
  - Superfamily Euproöpacea Raymond 1944.
    - Family Euproöpidae Eller 1938.
      - Genera: *Prestwichianella* Woodward, *Euproöps* Meek, *Pringlia* Raymond, *Anaconlium* Raymond.
    - Family Liomesaspidae Raymond 1944.
      - Genera: *Liomesaspis* Raymond, *Prolimulus* Fritsch.
    - Family Elleridae Raymond 1944.
      - Genus: *Elleria* Raymond.
    - Family Kiæridae Størmer n. fam.
      - Genus: Kiæria.
    - Unclassified:
      - Genus: *Pincombella* Chapman.
  - Superfamily Limulacea Raymond 1944.
    - Family Paleolimulidae Raymond 1944.
      - Genus *Paleolimulus* Dunbar.
    - Family Mesolimulidae Størmer n. fam.
      - Genera: *Psammolimulus* Lange, *Limulitella* Størmer n. nom. *Mesolimulus* Størmer n. gen.
    - Family Limulidae Zittel 1881–85.
      - Subfamily Limulinae Zittel, Pocock 1902.
        - Genus: *Limulus* Müller.
      - Subfamily Tachypleinae Pocock 1902.
        - Genera: *Tachypleus* Leach, *Carcinoscorpius* Pocock.

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TWO TRILOBITE GENERA FROM THE HARDING FORMATION (ORDOVICIAN) OF COLORADO

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ABSTRACT—One new genus and an undetermined species of the genus *Törnquistia* Reed have been collected from the Harding formation of Ordovician age in the Canon City area of Colorado. Two trilobite specimens are all that were found during detailed collecting in this area. A previously listed trilobite species is assigned to the new genus.

INTRODUCTION

THE two trilobite specimens were obtained by the junior author in the summer of 1950, while engaged in a field study of the Harding formation in the Canon City embayment. The small pygidium of *Törnquistia* was collected by Pollack, and the small, nearly complete, enrolled specimen was donated by Mr. W. S. Plant, a student at the University of Oklahoma field camp, who collected it from a nearby fossiliferous zone in the Harding formation.

An examination of the literature on the Harding formation revealed that only one species of trilobite had previously been reported. Kirk (1929, p. 493) reported "a trilobite similar to but distinct from *Pterygometopus intermedius* (Walcott)." Johnson (1945, p. 22) cites *Pterygometopus intermedius* (Walcott) in his faunal list, on authority of Kirk, although Delo (1935, p. 417) had previously assigned *P. intermedius* as the genotype of the new genus *Eomonorachus*. It is probable that Kirk's specimen which is not available for comparison was the same species as the enrolled specimen which we are assigning herein to *Isalaux* n. gen.

Unfortunately, no exact age determination of the Harding formation can be made on the basis of the trilobites. The Harding has been variously determined as lowermost Chazy by Branson and Mehl (1933, p. 21) on the basis of the conodont assemblage, and possible Black River by Walcott (1892, p. 159). Other authors on authority of Walcott's faunal list, have also attributed a possible Black River age to the Harding formation.

Törnquistia has been reported from Middle Ordovician strata in Europe, and the related genus *Dimeropyge* occurs in strata of Black River and Trenton age in North America and Europe.

Isalaux n. gen. has characteristics which are more advanced then *Calliops* and appears to have developed as an offshoot from the *Calliops-Eomonorachus* line of development (Delo, 1940, p. 90). Therefore, although *Calliops* occurs as early as Chazy, we believe *Isalaux*, with its specialized eyes, to be at least very late Chazy in its appearance. From the evidence of the two trilobite genera, therefore, the Harding may be late Chazy or early Black River in age.

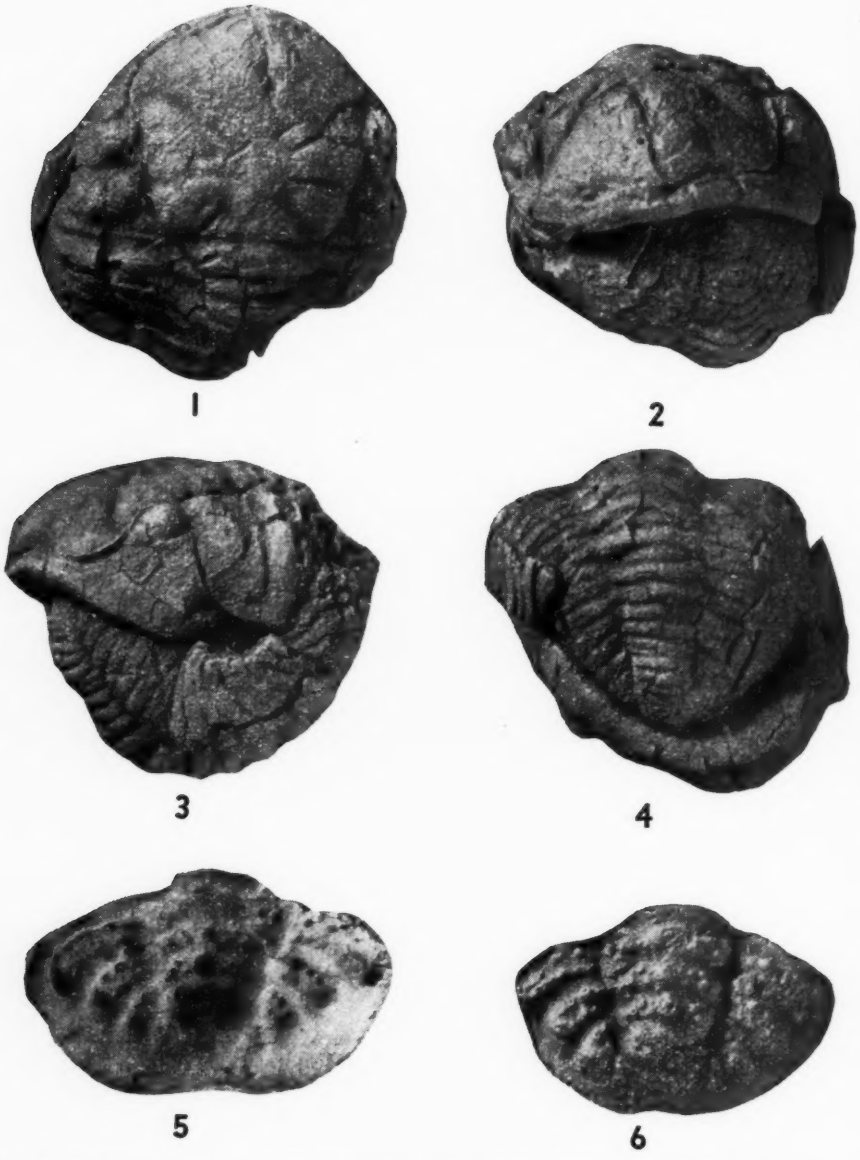
SYSTEMATIC DESCRIPTION

Family PHACOPIDAE Hawle and Corda, 1847
(emend. Delo, 1935)
Subfamily PTERYGOMETOPINAE Reed, 1905
Genus ISALAUX Frederickson and Pollack n. gen.

Genotype: Isalaux cañonensis Frederickson and Pollack, n. sp.

Generic Diagnosis.—Pterygometopinae with small raised eyes adjacent to first glabellar lobes. Dorsal furrows expanding anteriorly making frontal lobe wide but not alate; three pairs of lateral furrows, well marked; first and second glabellar lobes triangular, first lobes largest and separated from second lobes by straight second glabellar furrows. Pygidium submucronate with axial lobe extending to posterior margin.

Remarks.—The genus differs from *Pterygometopus*, s.s. in the shape and size of the lateral lobes, in the position of the lateral furrows and in the small eyes. The shape of



FIGS. *1–4—Isalaux cañonensis* n. sp. Holotype, cephalic, anterior, profile and pygidial view of enrolled specimen, ×5.
FIGS. *5–6—Törnquistia* sp. indet. *5*, chert internal mold of pygidium ×5. *6*, rubber cast of pygidium ×5.

the glabella and the three well-defined furrows outlining the triangular glabellar lobes are similar to *Calliops*. However, in *Calliops* the second lateral lobe is considerably smaller than the first and the second and third glabellar furrows are bent obliquely forward. In *Isalaux*, by contrast, the first and second lobes are nearly equal in size and the straight second glabellar furrow nearly bisects the angle formed by the opposed

obliquely trending first and third furrows. *Calliops* also has large eyes like *Pterygometopus*.

Isalaux is similar to *Eomonorachus* in the position of the glabellar furrows, and the pygidia of the two genera are nearly identical. However, the large eyes, distal obsolescense of the second furrow, and the distal tubercles of the third lobe in *Eomonorachus* are fundamental differences.

Both *Chasmops* and *Achatella* of the *Pterygometopinae* have small eyes similar to *Isalaux*, but the lobation of the glabella is very different in the three genera, and the posteriorly trending facial suture behind the eyes is apparently unique to *Isalaux*.

ISALAUX CAÑONENSIS
Frederickson and Pollack, n. sp.
Figs. 1–4

Cephalon subhemispheric, somewhat acute anteriorly and moderately convex. The glabella is widest across the frontal lobe and tapers posteriorly, the width across the occipital ring equaling about two-thirds the width across the frontal lobe. The glabella is convex, declining steeply to the front. There are three pairs of glabellar furrows of equal depth; the first pair trend obliquely backward, the third pair trend obliquely forward from the end of the occipital furrow, and the second pair are straight, bisecting unequally the angle formed by the first and third furrows. The glabellar lobes are triangular, the first pair large, the second pair about three-fourths as large as the first and the third pair of lateral lobes almost obsolete, consisting of a narrowing ridge ending short of the junction of the dorsal and occipital furrows. The occipital ring is convex. The eyes are small, appear round, and are located adjacent to the dorsal furrow opposite the anterior two-thirds of the first lateral glabellar lobe. That portion of the fixed cheek adjacent to the eyes is very narrow and appears to consist only of the steeply sloping palpebral lobe. There is no palpebral furrow and the eyes are so poorly preserved that is is impossible to determine the course of the facial suture between the eye and the palpebral lobe. It is possible that the eyes are crescentic as in other Pterygometopinae, although much smaller than in any other genus. The ocular platform is smoothly convex to the rounded border and the free cheek has no lateral marginal furrow. The posterior marginal furrow is well defined, trending laterally from the dorsal furrow to the genal angle, then forward, curving parallel to the facial suture and apparently forming a shallow furrow confluent with the facial suture to the base of the eye. The preglabellar marginal furrow is faint and fades out laterally. The border is convex and narrow anteriorly, continuous with the doublure. The anterior branch of the facial suture runs forward and outward along the dorsal furrow, curves around the base of the glabella parallel to the preglabellar furrow and then arches forward to intersect the furrow at the crest of the arch. The posterior branch trends outward and backward from the eye in a smooth convex curve intersecting the lateral margin near the short incipient genal spine.

Thorax with eleven segments. Axis raised, convex, dorsal furrow broad and shallow. Pleura bent forward laterally with very blunt termination.

Pygidium rounded, triangular, sub-mucronate. The axial lobe is convex and has twelve segments, eight well marked and four faint, including the rounded terminal segment. The sides slope steeply away from the axis. There are seven interpleural grooves continuing to the margin; no border is evident.

The holotype specimen retains only small fragments of the test, but the entire individual appears to have been ornamented with small tubercles.

Holotype.—O.G.M. 117-1-8, from a small saddle in the lower silty shale about thirty feet above the base of the Harding formation, NW¼, sec. 35, T.17S., R.69W., Fremont County, Colorado. The specimen was found with an abundant molluscan fauna including *Eccyliomphalus contiguus, Vanuxemia rotundata* and several species of *Ctenodonta*. Associated cephalopods, identified by Flower (1950), are *Ormoceras* and *Kionoceras*.

Family uncertain
Genus TÖRNQUISTIA Reed, 1896
TÖRNQUISTIA sp. indet.

The genus *Törnquistia* is represented by only one specimen, an external mold preserved in chert, of a highly ornamented

pygidium. The pygidium is convex and subovoid in shape. The axial lobe is convex, raised above the pleural lobes, and occupies one-third the width of the pygidium anteriorly. The axial lobe has three well-defined ring segments and a rounded terminal segment which taper posteriorly. The lobe extends a little more than two-thirds the length of the pygidium. There are three well-defined pleural ribs, two long, deeply curved furrows and one short posterior furrow. A steeply sloping smooth convex border, which is widest posteriorly, extends around the pygidium. The axial segments and pleural ribs are strongly tuberculated but the furrows and steep border are markedly smooth.

Remarks.—The pygidium closely resembles *Törnquistia translatus* (Reed), a species assigned to *Hystricurus* by Reed (1931, pp. 6–7) but shown by Whittington (1950, p. 563) to belong to *Törnquistia*. The Harding specimen has a smooth steeply sloping border and pustulose axial and pleural lobes like Reed's species. However, Reed in his original description (1904, p. 86) noted three ring-like segments to the axial lobe whereas the Harding specimen has three rings and a terminal segment. One of the two pygidia illustrated by Reed (1904, plate 12, fig. 6) shows a terminal segment, although the furrow between the third ring and the segment is very faint. The shape of the pygidium is more rounded than the triangular form of *T. translatus*.

Published specimen.—O.G.M. 117-1-9, on float covered slope of Harding, four feet above Manitou-Harding contact, SE¼, Sec. 33, T.17S., R.69W., Fremont County, Colorado.

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GENERAL ECOLOGY OF THE FORAMINIFERAL GENUS *EPONIDELLA* WITH DESCRIPTION OF A RECENT SPECIES

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ABSTRACT—A new species of *Eponidella* is described from Garden Island Bay, Louisiana, and the known range of the genus extended from Miocene to Recent. The shallow brackish-water habitat of the Recent species is strikingly similar to the depositional environments previously postulated for those sediments yielding the various fossil representatives of this genus.

INTRODUCTION

ALL three of the previously described species of *Eponidella* are of Miocene or lower Pliocene age. A Recent species is now known to occur in Garden Island Bay, near the mouth of the Mississippi River, off Plaquemines Parish, Louisiana, whose habitat is believed to have factors in common with the depositional environments of the fossil representatives of this genus. The associated organisms and a close similarity in test structures suggest a parallel mode of life among the Miocene species of *Eponidella* and a continuation in this type of habitat by the related Recent species.

This study mainly considers some of the more general environmental aspects of the genus. The sedimentation and microfauna of Garden Island Bay are contemplated as bases of more detailed future investigations.

The writer is indebted to the management of The California Company for permission to publish this paper and to Mr. A. L. Morgan, division geologist, for his encouragement in this type of study. The type figures are camera lucida drawings by the author.

THE DEPOSITIONAL ENVIRONMENT OF TERTIARY *EPONIDELLA*

Eponidella libertadensis *Cushman and Hedberg* (*1935, pp. 14–16*).—The genotype was described from Miocene shales near San Mateo, District of Libertad, State of Anzoategui, Venezuela. Although Cushman and Hedberg did not further describe their locality and horizon, beds near San Mateo have since been defined by Hedberg (1937, p. 2008) as part of the upper Santa Ines group. Liddle (1946, p. 492) places these in the upper Miocene and describes them as follows:

"The upper section includes gray, fissile, fossiliferous shale carrying clay-ironstone concretions, brownish sandstones, and sandy limestones terminating in hard, conglomeratic, arenaceous limestones and calcareous sandstones which form Dividive ridge eastward and northeastward from San Mateo. . . . The upper part of the group is well exposed under a capping of cemented gravel in the broad range of hills extending from Rio Putucual on the southwest along the southeast side of the road from San Mateo to South Ines. This horizon may be traced westward into red, purple, and gray gypsiferous shales, and hard, brown, conglomeratic sandstones outcropping between El Carito and La Margarita, and between La Margarita, San Pablo, and Cedeno."

The slight stratigraphic variation in species throughout the Santa Inesian sediments was interpreted by Hedberg (1937, p. 2011) as indicative of rapid deposition. He has identified several species of *Potamides* and a number of other shallow-water marine and brackish-water molluscan fossils from these beds. His conclusions based on a preliminary examination of the microfossils also point to a shallow-water marine and brackish-water origin in contrast to that of the typically more marine Carapita formation.

Liddle believed that the physical character of the Santa Ines group and the structural conditions in the area of its occurrence suggest deposition in a local brackish- or fresh-water lake which may

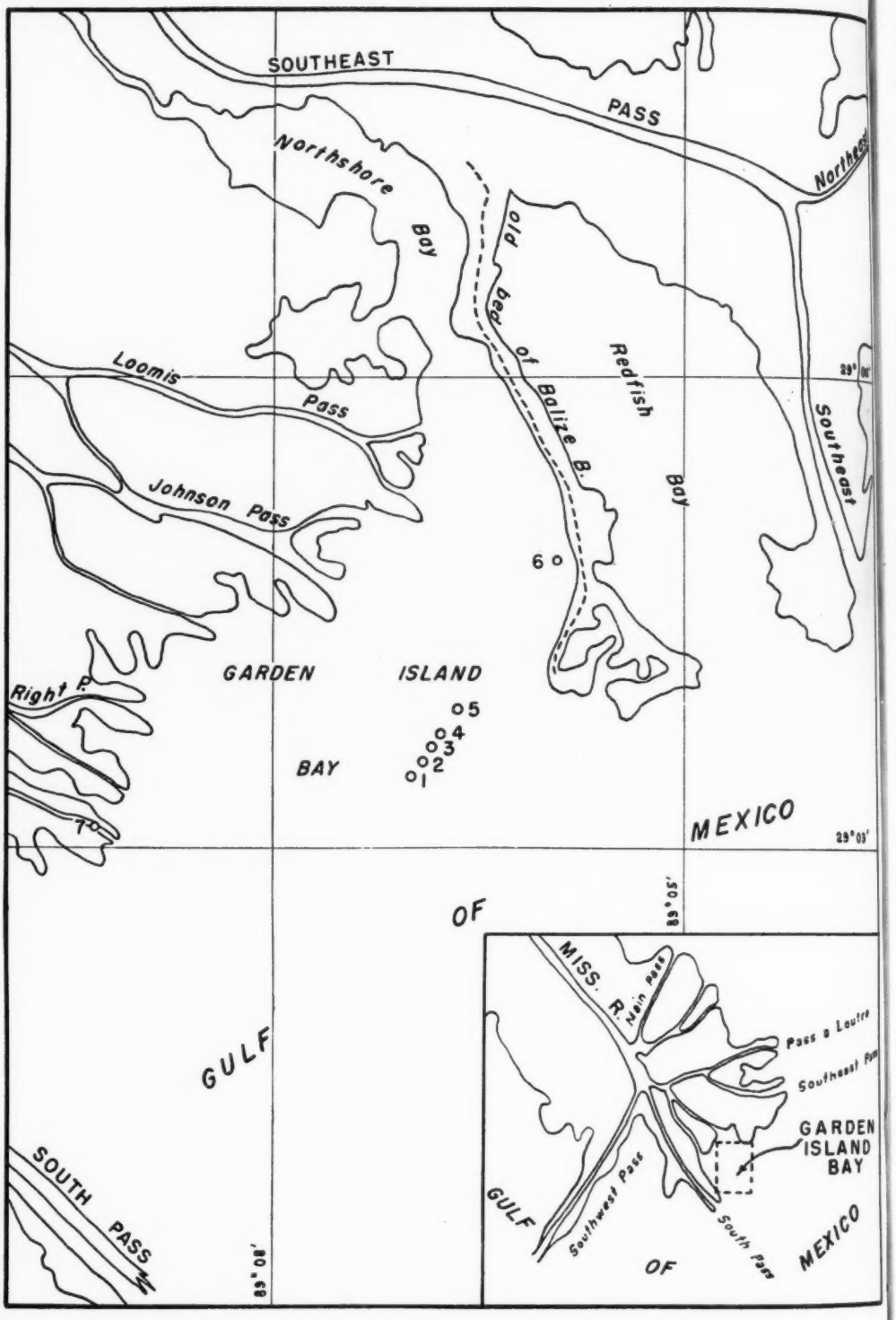

FIG. 1—Map of Garden Island Bay showing sample locations.

have drained into the Caribbean Sea when the mountain barrier on the north between Barcelona and Rio Chico was depressed below sea level. He pointed out a similarity to sediments of Ecuador and Colombia which were laid down "either in lakes temporarily cut off from the sea by mountains, or in arms of the sea which reached far inland."

Eponidella cushmani *Stephenson (1935, pp. 189–190).*—This species was described from the type locality of the *Potamides*

FIG. 2—*Eponidella gardenislandensis* Akers, n. sp. ×222; *a*, dorsal view; *b*, apertural view; *c*, ventral view; holotype, California Company Collection 101.

matsoni zone of Louisiana. Dall (1913, pp. 225–237) described a number of mollusks from this place and considered the age to be Pliocene. However, Matson (1917, p. 225), Johnson (1893, p. 90) and most Louisiana paleontologists of today identify the *Potamides matsoni* zone as upper Miocene.

Stephenson (1935, pp. 187–196) has also described the following ostracodes from the *Potamides matsoni* zone:

Microcythere (?) *moresiana*
Cytheridea (?) *matsoni*
Cytheridea locketti.

In the subsurface, *Eponidella cushmani* Stephenson is generally associated with a preponderance of *Streblus beccarii* var. cf. *tepida* (Cushman), *Elphidium incertum* (Williamson), and *Quinqueloculina* sp. Lowman (1949, p. 1956) associates this type of assemblage with a "bottom-living, open-water, strongly brackish and nearshore marine (inner neritic)" environment. It was on the basis of the molluscan assemblage, however, that Dall (1913, p. 227) earlier labelled the fauna of the type locality as "strictly brackish water." He reconstructed its environment as follows:

"The conditions appear to have been not unlike those which obtain at certain portions of the Gulf coast today; probably lagoons into which the streams poured fresh water carrying with it small fresh-water gastropods and occasionally valves of Unionidae. On the other hand, the sea had access to the lagoons, keeping the salinity of the water such that oysters and Anomias could flourish with other smaller mollusks which frequent oyster beds, while occasionally purely salt-water shells might be ejected by wandering fishes or carried by violent storms."

Ellisor (1940, p. 438) speaks of the subsurface *Potamides matsoni* zone's brackish water origin and describes it as generally consisting of green, calcareous, lignitic, sandy clays which grade into sands downdip. According to her, "*Potamides matsoni* Dall is found only in the northern part of the Atchafalaya basin and west of the Atchafalaya River. Eastward and downdip east of the Atchafalaya River, this brackish-water zone grades into the upper part of the marine *Uvigerina lirettensis* zone."

Eponidella cushmani Stephenson does not occur in this more marine facies but is frequent where the shallow-water gastropod, *Potamides matsoni*, is found.

Eponidella palmerae *Bermudez* (*1949, p. 261*).—This species from the Dominican Republic, according to Bermudez (1949, p. 261), was found to be "associated with a very shallow-water assemblage in which *Streblus beccarii* var. *parkinsoniana* (d'Orbigny) and *Elphidium gunteri* Cole predominate." A dominance of these species is characteristic of the "Brackish Assemblage" of Israelsky (1949, chart) which would lie in a position intermediate between Lowman's "bottom-living, open-water, moderately brackish" environment and his "bottom-living, open-water, strongly brackish and nearshore marine (inner neritic)" environment (1949, p. 1956). *E. palmerae* was described from sandy, granular limestone and gray, light-brown clay shale of upper Miocene age.

THE RECENT ENVIRONMENT OF *EPONIDELLA GARDENISLANDENSIS* AKERS, NEW SPECIES

Garden Island Bay (fig. 1) is located between the finger-like extensions of Southeast Pass and South Pass near the mouth of the Mississippi River, off Plaquemines Parish, Louisiana. Numerous minor distributaries discharge their waters directly into the bay, which, at South Pass, during high-water stage, are almost fresh enough to drink. At other times, the physical properties of the water in the bay, especially at the off-shore margin, are essentially the same as those of the open Gulf.

Mean low water varies from less than ½ foot near the inner part of the bay to 12 feet at the off-shore margin. All of the seven stations at which specimens of the genus *Eponidella* have been identified (fig. 1) are between ½ foot and 4 feet of water depth. Since water in the bay is so shallow, the bottom is affected by the diurnal temperature range. Bottom temperatures approximate those at the surface, and changes in atmospheric temperatures are quickly reflected on the bay floor.

Considerable sampling has shown that the character of the bay floor is quite variable from place to place, and it is probably this factor, which, more than any other influences the distribution of Foraminifera within Garden Island Bay. Those samples from the more turbulent portions of the bay had a relatively high sand content but a low concentration of foraminiferal tests and organic matter. Samples with a high organic content, particularly vegetable material, contained large foraminiferal populations. Only those stations at which *Eponidella* has been identified are shown in figure 1, and it is also these which yielded the largest foraminiferal concentrations.

Although distributary samples were examined from a number of localities in proximity to Garden Island Bay, only one (station 7) yielded specimens of the genus *Eponidella*. Their frequency here is very low, as are other foraminiferal species at this point. To date, *Eponidella* has not been identified from tidal stream or marsh environments, which have been rather thoroughly sampled, nor was it found in the deeper waters whose bottoms have been sampled off South Pass.

Optimum conditions for the success of Recent representatives of the genus appear to prevail at station 2 where its tests constitute 13 per cent of a total foraminiferal population (all benthonic) of 147. Other species and their relative frequencies in per cent in a sample from this station are as follows:

Ammobaculites sp.	51
Elphidium poeyanum (d'Orbigny)	23
Streblus beccarii var. *tepida* (Cushman)	12
Elphidium excavatum (Terquem)	1

The associated genera as represented herein characterize Lowman's "moderately brackish, bottom-living, open-water" environment (1949, p. 1956).

SYSTEMATICS

Order FORAMINIFERA
Family ROTALIIDAE
Genus EPONIDELLA Cushman and Hedberg, 1935

EPONIDELLA GARDENISLANDENSIS
Akers, n. sp.
Fig. 2, a–c

Test small, consisting of two whorls, biconvex, trochoid, the dorsal side more elevated than the ventral, ventral umbilical region closed and slightly depressed, periphery broad and rounded; chambers seven

to nine visible on both sides of the final coil, distinct in the outer dorsal whorl but usually indistinct in the inner, inflated, enlarging little in width but gradually in length as added, final chamber strongly inflated ventrally and constituting thickest portion of test, small supplementary chambers of triangular shape added ventrally from umbilicus to $\frac{1}{3}$ distance to outer periphery; sutures slightly depressed, the spiral suture less distinct and not so limbate as the chamber sutures; wall calcareous, coarsely and uniformly perforated; aperture large, the widest part an oval opening in the central portion of the septal face but extending as a slightly narrowed projection to the ventral margin of the apertural face. Length of holotype, 0.23 mm.; breadth, 0.20 mm.; thickness, 0.15 mm.

Holotype No. 101 from Recent sediments at California Company station 3, Garden Island Bay; deposited in The California Company Collection, New Orleans, Louisiana.

This species compares more closely with *Eponidella cushmani* Stephenson than with the other described species. It differs from the fossil form, however, in having a greater relative thickness of the test, fewer whorls, fewer chambers in the final coil, greater inflation of the chambers, a smaller relative area occupied by the supplementary chambers, and in the character of the aperture which has not been seen to be variable as in *Eponidella cushmani* Stephenson and *Eponidella libertadensis* Cushman and Hedberg.

SUMMARY AND CONCLUSIONS

All of the known fossil species of *Eponidella* are considered to have had a shallow, brackish-water habitat, whether bay, lagoon, or land-locked brackish lake. Since Schenck (1940) and others (Israelsky, 1949; Lowman, 1949) have described an abundance of specimens of *Streblus beccarii* (Linné) as indication of shallow, brackish-water deposition, the general association of this species or its varieties with *Eponidella* is in itself strongly suggestive of such a conclusion. The occurrence of a Recent species of *Eponidella* in an environment similar to that earlier postulated for Tertiary members of the genus by investigators in Venezuela, the Dominican Republic, and subsurface Louisiana is an interesting discovery from the standpoint of ecology. The known range of the genus is extended by this discovery from Miocene to Recent.

The close resemblance of *Eponidella gardenislandensis*, new species, to *Eponidella cushmani* Stephenson and the occurrence of the Recent species in the same general area as that of the fossil suggest a close evolutionary relationship. Subsequent sampling of both Recent and Tertiary sediments from the Gulf of Mexico region may shed light on the development and method of distribution of members of this genus.

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TRIASSIC CONODONTS FROM SOUTHEASTERN IDAHO

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ABSTRACT—Ammonoid-bearing limestone from Lower Triassic rocks of southeastern Idaho collected during the summer of 1949, yielded conodonts when treated with glacial acetic acid. These specimens are true conodonts and at least five genera are represented. They do not appear to have been reworked from older sediments, they seem to fit well as Triassic conodonts into the known evolutionary trends of conodonts, and they are probably indigenous to the strata from which they were secured. As is commonly the case in the Paleozoic, these Mesozoic conodonts are also associated with abundant fish remains. The previously reported occurrence of conodonts in the Triassic of Egypt, and the present discovery in Idaho, indicate that they did not become extinct near the end of the Paleozoic as has been commonly supposed. Several contemporary students of conodonts have also studied these specimens from Idaho and their observations are included in this paper.

INTRODUCTION

DURING the summer of 1949, a large number of samples of Late Paleozoic rocks and a few from Mesozoic rocks were collected in southeastern Idaho. This material was utilized in a study of the microfaunas of these terrains. While working along the northeastern flank of the Bear River Range, and as a matter of incidental collecting, some cephalopods were secured from what are believed to be high Lower Triassic rocks—probably part of the Thaynes formation—for the paleontological collections at the University of Idaho. A large number of ammonoids (and a few nautiloids) were obtained. Later, in routine laboratory processing of all of the samples, a few of these Triassic cephalopod internal molds (with a small amount of matrix attached) were dissolved in glacial acetic acid. The cephalopods and matrix dissolved readily. The fossil portion of the residue included a few internal molds of pelecypods, many miscellaneous parts of cephalopods, a large number of gastropod internal molds, numerous fish remains, and a moderate number of conodonts. To avoid any possibility of misinterpretation of the foregoing statements, it should be added that the writer believes that the conodonts are in no way zoologically related to the cephalopods, and that they merely were a part of the sediments which filled the cephalopod shells forming the internal molds. Because the material was collected originally for the cephalopods which it contained, the conodonts were derived largely from these cephalopod steinkerns. However, they occur also in the matrix.

REPORTS OF OTHER MESOZOIC CONODONTS

Previous to this discovery, authentic conodonts have been recorded from Mesozoic strata only twice,[1] but in both instances their indigenous relationship to the containing beds was questioned. In 1941, Branson and Mehl noted that conodonts have been reported from the Hauptmuschelkalk of Neustadt, Germany, but these authors stated (Branson and Mehl, 1941, p. 191) that "we do not consider that they are a record of Mesozoic conodonts, but of residue from Pennsylvanian or Permian formations." More recently, Eicher (1946) called attention to the presence of conodonts in Middle Triassic rocks of northeastern Egypt. Appended to Eicher's paper is a discussion of the find by Branson and Mehl who suggest that in this case also "the possibility of an introduction of older conodonts into the accumulating sediments does not seem entirely eliminated."

PRESENT COLLECTION

In attempting to establish the Triassic age of the Egyptian conodonts, Eicher

[1] For the sake of completeness it should be added that Gunnell (1932) reported conodonts in the Cretaceous of Texas, but it is doubtful if the specimens were conodonts.

cited three facts which must be established: "(1) that the microfossils in question are true conodonts; (2) that the sediments in which they are found are really Triassic; and (3) that they are indigenous to this formation, that is, not redeposited from some other formation." He concluded that the conodonts from Egypt were true Triassic specimens. These same tests have been applied to the specimens now known from southeastern Idaho with additional criteria of the apparent evolutionary position of the conodonts, and their resemblance, if any, to those of older known faunas. These points are here considered.

Age of containing sediments.—The specimens from southeastern Idaho were found in a residue resulting from dissolving Triassic ammonoids belonging to at least two different genera. (A few nautiloids of no great stratigraphic significance were also collected and dissolved, and likewise yielded conodonts). The ammonoids have been studied by Muller who comments that "the *Columbites*-like forms and species resembling *Sibirites* suggest a stratigraphic position high in the Lower Triassic." There can be no doubt, therefore, that these conodont-bearing beds are of Triassic age.

On the problems of the nature of the specimens (conodonts or not?), and their apparent evolutionary position, the judgments of several students of conodonts were solicited by means of a questionnaire which was circulated together with a representative group of specimens. These conodonts were all obtained from one unit of residue and were selected only to give representative variety to the collection, irrespective of their fragmental or whole condition. The following persons who have all recently contributed to conodont literature, received the same slide of specimens: C. L. Cooper, D. B. Eicher, Samuel Ellison, W. M. Furnish, W. H. Hass, and M. G. Mehl. The questionnaire contained the following queries: "(1) Are these specimens conodonts? (2) Have you ever seen specimens from Paleozoic rocks which would duplicate these? (3) Based upon the known trends of conodont evolution in the Late Paleozoic, do you believe this assemblage, from an evolutionary point of view, would be compatible with an Early Triassic age? (4) Do you believe these specimens show signs of having been reworked from older beds?"

Opinions received on these points, and the writer's opinions together with supplementary information from field evidence follow.

Are these conodonts?—There is unanimous agreement among all the individuals questioned that these Lower Triassic specimens from southeastern Idaho are true conodonts.

Resemblance to older known faunas.—The present assemblage definitely does not resemble any fauna so far described from Pennsylvanian or older rocks. The general lack of described Permian faunas to date precludes satisfactory comparisons with conodonts of that age. However, a few Permian conodonts have been described and/or figured by various authors. In this connection, Ellison noted on the questionnaire that these Idaho Triassic specimens "are like those described by Branson and Mehl from the Hauptmuschelkalk of Germany" (which may possibly have been true Triassic forms); Ellison also suggested that they are similar to some of those illustrated by Branson and Mehl (1941, pl. 7) from the Phosphoria of Wyoming, and to those described by C. C. Branson (1932) from the same formation. Mehl also replied that the most common form (the *Gondolella*-like genus) "is very similar to conodonts purportedly from the Muschelkalk of Germany" and added that "some of the others might well be [referred to] long ranging Paleozoic types." As just indicated, there are several generalized long ranging types of conodonts (e.g., forms somewhat similar to *Ozarkodina*, and *Hibbardella* or *Trichognathus*) in this Triassic conodont assemblage. Also, the platform type of conodont termed *Gondolella* in the Paleozoic exists in this Triassic fauna in a form which is somewhat similar to those specimens known from the Phosphoria formation. However, recently Youngquist, Hawley, and Miller (1951) studied conodonts secured from the Phosphoria formation in the region (within a mile) where these Triassic conodonts were collected. A direct comparison of the Phosphoria conodonts with the Triassic specimens indicates clearly that there are

many differences between the Permian and Triassic specimens, and these two faunas, on the basis of these platform-type conodonts alone, would be easy to distinguish. It is the writer's opinion that this Triassic assemblage, as a whole, and the individual specimens, to a large extent, are quite distinct from any previously described collections or individuals from Paleozoic strata.

Apparent evolutionary position of these conodonts.—All correspondents agree that the conodont assemblage would, from the known evolutionary trends of conodonts, be compatible with an Early Triassic age. However, some also suggested that the specimens might be compatible with a Middle or Late Permian age, but lack of described faunas from rocks of these ages precluded satisfactory comparisons at this time.

Although Permian conodont faunas, and therefore evolutionary trends in the Permian, are not well known, the fauna recently described (Youngquist, Hawley, and Miller, 1951) from the Phosphoria formation near where these Triassic conodonts were collected elucidates a few points. In addition, unpublished studies of specimens from the Lower Permian of Kansas are available for reference. The persistence of *Gondolella* into the Permian is a well established fact, and at least in the Phosphoria formation (Middle Permian) that genus appears to be the dominant element. *Idiognathodus*, which was common during the Early and Middle Pennsylvanian but became progressively less abundant toward the Late Pennsylvanian, is absent in the Phosphoria assemblage available for study, and *Streptognathodus*, which is abundant in Early Permian rocks is represented by a relatively few specimens in the Phosphoria. This general trend of the persistence of *Gondolella*-like forms and the partial or perhaps complete elimination of other platform type conodonts is clearly evident in this Triassic fauna. The general form of *Gondolella* is distinctly carried on in these Triassic specimens; the modifications thereof are no more than might be expected for the time lapse involved. Mehl has commented that "the outstanding form is undoubtedly derived from *Gondolella*. . . . This is most likely a new genus but it would be difficult to word the diagnosis so as to clearly define this Triassic form." One of the evolutionary trends of *Gondolella* from the Pennsylvanian into the Permian is a reduction in size. This trend is likewise continued into the Triassic by the form apparently derived from *Gondolella*. It should be added that to a lesser extent a progressive reduction in size of nearly all elements in the Pennsylvanian and Permian conodont faunas is evident from about the middle of Pennsylvanian time, and the generally small size of the Triassic conodonts under consideration is compatible with their apparent stratigraphic position.

As is common in the Late Paleozoic faunas, most of the genera of conodonts, other than the platform type, in this Triassic assemblage are generalized long ranging forms. Among these are the forms which from Paleozoic rocks are termed *Spathognathodus*, *Ozarkodina*, and *Trichognathus*.

Briefly, it seems to the writer that the composition of the present fauna, the size of the individual specimens, and the general but not detailed similarity of these forms with described Late Paleozoic specimens are facts entirely compatible with a Triassic age assignment of these conodonts.

Do these specimens show signs of having been reworked?—All correspondents receiving the specimens and questionnaire evidenced doubt to a greater or lesser extent that these conodonts were reworked from older sediments. All agreed that the specimens showed no signs of having been reworked.

As indicated, evidence that the conodonts are indigeous to the Triassic strata in which they occur is suggested by the apparent lack of signs of reworking among the specimens and the excellent state of their preservation. The specimens are small, averaging a little less than 1 mm. in maximum length, and it might be that fossils of this size would not be abraded to any appreciable extent in the process of being eroded from their original site of deposition, and redeposited in younger beds. However, the very delicate nature of many of the specimens, particularly the elongate bar or blade-like forms, would increase the hazards of reworking. Some specimens are undoubtedly broken

during the glacial acetic acid treatment and subsequent washing; but it seems significant that many very fragile specimens are found intact. For that fact alone, it is doubtful that they have been reworked from older formations. It is also significant that no other fossils (such as the numerous gastropods, pelecypods, and fish remains) found in the residue give evidence of being reworked. Recently, the Paleozoic formations of southeastern Idaho have been sampled in some detail for their microfossil content but no conodont faunas were found which resembled this Triassic collection.

Finally a significant fact was disclosed through correspondence with C. L. Cooper and W. H. Hass. They state (letter dated Mar. 14, 1951) that "the collections at the National Museum furnished enough material to verify your find and to extend the area of occurrence of Triassic conodonts about 50 miles north and 10 miles east of your locality. . . . " This apparent widespread occurrence of conodonts in the Triassic rocks of southeastern Idaho is a further evidence of their indigenous relationship to the rocks in which they occur. That is, it seems unlikely that reworked conodonts would be widely distributed, for the Triassic sediments of this area were probably derived from terrains presenting rocks of several ages and varieties (possibly some igneous) all of which were eroded in Triassic seas. If one or two Paleozoic formations yielded conodont-bearing sediments to Triassic seas, the distribution of the conodonts would probably be geographically sporadic in Triassic sediments. Conodonts are apparently also widely distributed in the Triassic of Egypt and Palestine, for in a letter sent from Saudi Arabia April 3, 1951, Eicher states that shortly after writing his two preliminary papers on the conodonts from Egypt he "found additional conodonts in the Triassic at another locality. This seems to be all that is needed to substantiate beyond reasonable doubt that they are indigenous to the formation. The second locality is in southern Palestine, about 40 kilometers northeastward along the strike of the beds from Gebel Araif el Naga, where the first conodonts were found. Here again definite Triassic megafossils were collected below the conodont-bearing shales. Altogether I have about 100 specimens from the Sinai locality and about 50 from Palestine." The widespread occurrence of conodonts in Triassic sediments of such widely separated localities as Egypt and Palestine, and southeastern Idaho is strong evidence for assuming that the conodonts are true Triassic specimens.

ASSOCIATION WITH FISH REMAINS

At the present time, it seems that if there is any one field guide which can be used to indicate the probable presence of conodonts in marine strata, it is the occurrence of an abundance of fish remains. Examples of this association are numerous (Branson and Mehl, 1941, p. 191; Bryant, 1921; Furnish, 1938; Hibbard, 1927; Kirk, 1929; Pander, 1856; Youngquist and Heezen, 1948; Youngquist and Patterson, 1949; etc.) The presence of conodonts with fish remains may be purely a coincidence or it may be that the conodont-bearing animals favored an ecology like that of fishes. Or conodonts may be parts of fishes. For several reasons, the popularly held concept that conodonts are fish teeth does not seem tenable, but they may have been internal supporting structures in certain fishes, as suggested by Hass and others. In any event, it is noteworthy that the association of conodonts with fish remains, which is so commonly the case in the Paleozoic, continues, at least in this instance, into the Mesozoic for parts of sharks' teeth and dermal denticles are very abundant (much more common than the conodonts) in the residue. A number of these fish remains were submitted to Bobb Schaeffer who states that the "shark teeth . . . probably belong to the genus *Polyacrodus*. The dermal denticles come from some hybodont shark, possibly either *Hybodus* or *Acrodus*. . . . The bits of denticulated bone may very well be from the basal portions of a fin-spine of one of these sharks."

CONCLUSIONS

It is the unanimous opinion among those students of conodonts who were polled, that these specimens from Lower Triassic strata in southeastern Idaho are true conodonts. It is generally thought that their apparent evolutionary position is in agree-

ment with an Early Triassic age, and that the specimens are probably indigenous to the Triassic rocks from which they were secured. These are also the writer's conclusions.

It seems, therefore, that the minimum geologic range of the conodonts is from Early Ordovician to the Middle Triassic (apparently in Egypt), and that the time at which conodonts became extinct cannot now be ascertained from the information available. These Early Triassic Idaho specimens represent at least five genera and several species. Conodonts have apparently waxed and waned in both diversity and abundance several times on the North American continent, and the abundance and variety of conodonts in these Early Triassic sediments is no less than that which we, at present, know of conodonts in certain portions of the Late Mississippian, for example. The marked expansion of conodonts in abundance during the Pennsylvanian is well known. Conodonts probably do not show such an expansion in post-Middle Triassic times, for if they did, that fact would probably have been noted long ago in connection with some of the numerous micro-studies of Mesozoic sediments. However, it appears now that conodonts survived into the Early and Middle Triassic, and perhaps later.

COLLECTING LOCALITY

The locality which yielded these Triassic conodonts is easily reached. The specimens were obtained from very fossiliferous cephalopod-bearing limestone lenses in a predominantly argillaceous portion of the Thaynes formation in the SE $\frac{1}{4}$, Sec. 6, T. 14 S., R. 43 E., Bear Lake County, Idaho. This locality is about one mile west of the town of Paris, and is on a ridge between Slights (also spelled "Slight") Canyon and Paris Canyon. Mansfield (1927, geologic map, pl. 9; spelled "Slight" Canyon here) indicates that this is part of a well defined syncline. The fossiliferous limestone lenses do not crop out immediately at the surface but are covered over by a few inches of shale wash. However, some float is evident, and the limestone can easily be dug out by means of a hand shovel. Since the original discovery of conodonts here, a moderate amount of additional rock has been secured. If any readers are interested in having some of this material, the writer will be glad to supply it upon request.

Acknowledgments are due Dr. Siemon Wm. Muller of Stanford University for his observations on the ammonoids associated with the conodonts, to Dr. Bobb Schaeffer of The American Museum of Natural History for identification of the fish remains, and to Mr. D. B. Eicher of Aramco, Dhahran, Saudi Arabia, for information about Triassic conodonts from Palestine, and additional notes on those already reported from Egypt. The cooperation of Drs. C. L. Cooper, Samuel Ellison, W. M. Furnish, W. H. Hass and M. G. Mehl in offering their remarks on these Idaho specimens is likewise appreciated. Mr. and Mrs. A. E. Thiel of Montpelier, Idaho originally called the writer's attention to the occurrence of this Triassic cephalopod zone in Slights Canyon. The field work was part of a series of studies supported by Special Research Project 23 of the University of Idaho. Mr. R. W. Hawley was field assistant on this project during 1949.

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PALEONTOLOGICAL NOTES

A NEW HYDROZOAN FROM THE DEVONIAN OF MICHIGAN

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INTRODUCTION

Mr. George W. Byers of the Department of Geology, University of Michigan sent some Silurian dendroid graptolites on glacial drift fragments for identification, and with them two large and several small fragments of white coarse friable sandstone in which parts of a hydrozoan are well-preserved. The sandstone fragments were collected by Mr. Byers in July, 1947, from the Middle Devonian, Sylvania sandstone of the Detroit River group from the Quarry of the Michigan Silica Company, one mile southeast of Rockwood, Wayne County, Michigan.

The hydrozoan is elongate cylindrical with a central axis from which numerous branches radiate in all directions. When found in the quarry, the colony had been split longitudinally near the center exposing the central axis. Then it was broken transversely into two larger fragments and several smaller ones.

The form is new both as to genus and species. It is placed in the Family *Plumularidae* and is compared mostly closely with *Antennularia fascicularis* Allman (Allman, 1833, p. 24). The new genus is *Archaeoantennularia* Decker and the new species *A. byersi* Decker.

SYSTEMATIC DESCRIPTION

ARCHAEOANTENNULARIA Decker, n. gen.

The type of the new genus is the form collected by Mr. Byers as noted above. The hydrosome or colony is cylindrical with a central axis from which hydrocladia or branches in great numbers radiate in all directions. The central axis consists in part of large gonangia or reproductive organs, and in part, of hydrothecae which housed the hydrozoan polyps. This differs markedly from the central axis of *Antennularia* which consists of numerous definite coalesced tubes which connect laterally by pores through the sides of the tubes. The new genus differs from the earlier Middle Cambrian genera *Archaeocryptolaria* Chapman and *Archaeolofoea* Chapman in that those two genera have a simple single central axis to which the hydrothecae are attached (Chapman and Thomas, 1936, pp. 197-202).

ARCHAEOANTENNULARIA BYERSI Decker, n. sp.

The type of the new species is the form collected by Byers as noted above, and the species is named for the collector. Hydrothecae and gonangia compose the central axis from which the hydrocladia or branches radiate in great numbers in all directions. Some branches divide into numerous hair-like filaments. Most Recent hydrozoa have two rows of branches on opposite sides of the axis.

This new Devonian species compares most closely with the Recent *Antennularia fascicularis* Allman because the latter similarly has numerous branches radiating irregularly from all sides of a central multitubular (polysiphonic) axis.

Forms illustrated in Figs. 1, 2, 3, 4, 5, 7 belong to the hydrosome or colony taken as the holotype, and the one shown in Fig. 6 represents part of a smaller colony of the same species as paratype.

The height of the colony measured along the axis in Figs. 1, 2, 3, is 92 mm. This amount is increased by 17 mm. in the longitudinal section of the domed top of the colony shown in Fig. 7, making a total height of 109 mm. (about 4½ inches). Recent hydrozoans vary in height from a fraction of an inch to 9 inches.

The diameter of the colony with the branches bent is a little less than 20 mm., but when the branches are straightened, it becomes over 30 mm. Photographs shown

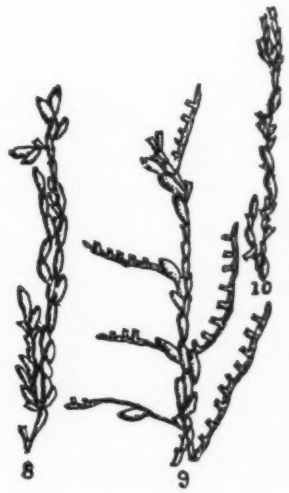
in Figs. 1, 2, 3, 6 have been retouched to make the structure clearer.

In the transverse section shown in parts 4 and 5 cemented together, the branches subdivide into numerous thread-like filaments, and they divide similarly in the longitudinal section of the top of the colony shown in Fig. 7. Magnification shows both hydrothecae and gonangia in the branches below the figure 7.

Figures 8, 9 and 10 represent camera lucida drawings by the writer of parts of the forms shown in Figs. 3, 6 and 1 respectively ×4.

In Fig. 8 representing part of the central axis shown in Fig. 3, the axis is composed dominantly of gonangia with only a few hydrothecae appearing. Fig. 9 represents a part of the fragment of the younger paratype in Fig. 6 of the same species in which hydrothecae form a larger part of the axis. Gonangia appear not only in the axis but also on some of the branches as seen on the lowest one at the left. Hydrothecae occur at right angles to the direction of the branches numbering about 20 in 10 mm. Fig. 10 represents an enlargement of part of the axis of the holotype shown in Fig. 1. This part of the axis consists still more largely of hydrothecae with only a few gonangia present.

FIGS. *1–7*—*Archaeoantennularia byersi* Decker, n. sp. *1, 2, 3*, photographs (retouched) of longitudinal sections of colony showing numerous branches which radiate in all directions from the central axis, ×1; *4, 5*, photograph of two fragments of transverse sections cemented together showing hydrocladia branching into numerous hair-like filaments, ×1; *6*, photograph (retouched) of longitudinal section of a young smaller colony used as paratype, ×1; *7*, photograph of part of a longitudinal section from the top of the colony, ×1.



FIGS. *8–10*—*Archaeoantennularia byersi* Decker, n. sp. *8*, camera lucida drawing of the axis of form in Fig. *3* showing numerous large gonangia and a few hydrothecae, ×4; *9*, camera lucida drawing of part of axis of the form in Fig. *6*, showing gonangia and hydrothecae, and branches on which hydrothecae and some gonangia occur, ×4; *10*, camera lucida drawing of part of axis of Fig. *1* composed chiefly of hydrothecae and a few larger gonangia, axis apparently incompetent to hold the growing colony erect without the support of the accumulating sand which was being deposited around it, ×4.

Discussion.—The dark part around the figure 2 represents interlacing strands of the

hydrozoan. If this represented an early stage, one might wonder if the vertical axis with its branches was developed as an adaptation to its environment in which it grew upward with its branches to keep part of the colony above the surface of the rapidly accumulating sand.

Hydrozoans have been described from the Middle Cambrian of Australia (Chapman and Thomas, 1936), from the Upper Cambrian of Texas (Decker, 1945), from the Ordovician Schenectady formation of New York (Howell, 1949), and from the Ordovician of Australia (Chapman and Skeats, 1919).

As hydrozoans occur quite commonly with graptolites, some of them have been described by the writer and by Ruedemann. Some genera described by Ruedemann as graptolites are now considered hydrozoans by Chapman as follows: *Acanthograptus*, *Cactograptus*, *Chaunograptus*, *Mastigograptus*, and *Thallograptus*.

The writer found hydrozoans also in the Ordovician part of the Arbuckle limestone, in the Viola limestone, and Athens shale; in the Silurian Henryhouse shale, and the Devonian Haragan marl.

Types.—As indicated above, the fragments shown in Figs. 1, 2, 3, 4, 5 and 7 represent parts of the holotype, and the fragment shown in Fig. 6 represents part of the paratype of a younger, smaller form of the same species.

The parts of the colony illustrated in Figs. 1 to 7 will be placed in the Museum of Paleontology, University of Michigan, and three other small fragments in the Museum of Paleontology, University of Oklahoma.

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THE *DOLICHOPTERUS-STROBILOPTERUS* GROUP IN THE EURYPTERIDA

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The genus *Dolichopterus* was erected by Hall (1859, p. 414) as a subgenus of *Eurypterus* for an eurypterid (*D. macrocheirus*) from the Silurian Bertie waterlime of western New York. Later authors, in particular Clarke and Ruedemann (1912, p. 258), recognized *Dolichopterus* as a separate genus from *Eurypterus*. The latter noted that *Dolichopterus* had characteristics more in common with *Stylonurus* than with *Eurypterus*. It was however referred to the Family Eurypteridae, as at that time the Eurypterida comprised only of the two families, Eurypteridae and Pterygotidae.

Diener (1924, p. 22) established the Family Stylonuridae but failed to recognize the stylonurid qualities of *Dolichopterus* which was referred to the Eurypteridae. Størmer (1934, p. 103) considered *Dolichopterus* as a genus of the Stylonuridae.

Dolichopterus has arcuate, compound eyes, a narrow, elongated, metastoma and wing-like epimera developed on the tergites which are characteristic of the Stylonuridae. However, it differs from that family in the forward position of the compound eyes and in particular in the development of the swimming leg in which the ultimate joint, or transtarsus, forms part of the paddle.

Another genus with general Dolichopteroid characteristics was described by Ruedemann (1935, p. 129) as *Strobilopterus* based on specimens from the Lower Devonian fish beds at Beartooth Butte, Wyoming. Ruedemann emphasized that his genus had similarities to both *Dolichopterus* and *Pterygotus*. The detached, broad, pterygotid telson led Ruedemann to a restoration of *Strobilopterus* in which he erroneously substituted the large chelicerae, armed with teeth, and the slender, undifferentiated walking legs of *Pterygotus* (1935, text fig. 6). Both structures were then unknown in *Strobilopterus*. As a result, *Strobilopterus* became associated with the Pterygotidae. The presence of the peculiar, swimming leg however, has always puzzled those who have worked with the Eurypterida.

Recently, through the kindness of B. F. Howell, the writers were able to review the original specimens of the peculiar *Strobilopterus*. The chelicerae were uncovered in the holotype, and these consist of simple elongated pincers not unlike those of stylonurid forms. The discovery of the chelicerae (see fig. 1) proves that the holotype of *Strobilopterus* was a form not related to any of the Pterygotidae. It also proved that some of the specimens referred to *Strobilopterus* definitely represent a *Pterygotus*. As a result of this review the writers refer the large telson (Ruedemann, 1934, pl. 2) and the large fragment of a tergite (Ruedemann 1935, pl. 3) to *Pterygotus*, which is described as a new species in the succeeding paper. The other specimens properly belong to *Strobilopterus*.

The writers do not agree with Ruedemann on details of the swimming (6) leg. Ruedemann (1935, text fig. 5) noted an extra lobe or joint which he designated "P". This structure is not present but is due to bending of the supplementary lobe of the tarsus. Figure 2 represents the writer's interpretation of the distal part of the swimming leg. It should be noted that all lobes are movable, articulating with their corresponding joints.

The genus *Strobilopterus* as now emended is characterized by compound eyes located anteriorly on the dorsal shield, a narrow, elongated metastoma, and in having the sixth paired appendage with supplementary lobes and in which the transtarsus is developed as part of the swimming paddle. All of these characteristics are much like in *Dolichopterus*. The writers therefore propose that a new family be erected to include *Dolichopterus* and *Strobilopterus* as a group distinct from any of the existing families.

This new family, herein named Dolichopteridae, has distinct affinities with the Stylonuridae and Rhenopteridae and therefore should be included in the Superfamily Stylonuracea. It differs from the Stylonuridae in the development of swimming legs and the position of the compound eyes, and differs from the Rhenopteridae not only in the same structures but also in the form of the metastoma.

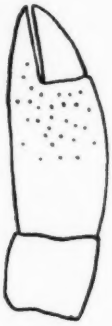

FIG. *1*—Chelicera of *Strobilopterus princetonii* (Ruedemann).

Family DOLICHOPTERIDAE nov.

Stylonuracea with anterior located, compound eyes, appendages increasing in length posteriorly; fifth and sixth paired appendages with supplementary lobes; sixth paired appendages developed as slender paddles with transtarsus enlarged to form part of the paddle; metastoma narrow, elongated; male median appendage very long; epimera of tergites commonly wing-like; telson spike-like.

Type genus.—Dolichopterus Hall, 1859.

It is suggested that *Dolichopterus* and *Strobilopterus* be included in this family.

Genus DOLICHOPTERUS Hall 1859

Dolichopteridae of medium size; test apparently smooth except for circular scales on certain appendages; prosoma, subquadrate; compound eyes situated close to antelateral angles; ocelli centrally located; ventral doublure unknown; chelicera unknown, probably small, simple; second to fourth paired appendages stout, increasing in length posteriorly, spinous; fifth and sixth paired appendages with supplementary flat lobes on distal joints, ultimate joint (transtarsus) forming a large claw in the fifth, and a broad, greatly enlarged lobe in the sixth appendage, lateral margin of paddle slightly serrate; metastoma narrow, cordate anteriorly, truncated at base; male median appendage very long, jointed; female appendage very small, not well known; no appreciable contraction of metasoma; posterior tergites produced into wing-like epimera; telson spike-like.

Type species.—Eurypterus (Dolichopterus) macrocheirus Hall, 1859.

Known distribution.—New York, Pennsylvania, West Virginia and possibly Saaremaa (Oesel).

Known stratigraphic range.—Ordovician and Silurian.

Genus STROBILOPTERUS Ruedemann, 1935 emend.

Dolichopteridae of medium size; test covered with pustules and semi-lunar scales; prosoma semiovate; compound eyes sub-

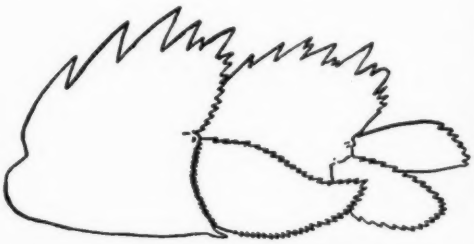

FIG. *2*—Ventral side of distal end of swimming leg of *Strobilopterus princetonii* (Ruedemann).

marginal; ocelli unknown; ventral doublure unknown; sixth appendages with movable, supplementary flat lobes on distal joints, ultimate joint (transtarsus) forming large, flat lobe; distal joints and lobes forming paddle, with strongly serrate margin; metastoma very narrow, cordate at anterior end; base unknown; male median appendage very long, consists of one undivided joint; metasoma contracted past first tergite; telson unknown.

Type species.—Pterygotus princetonii Ruedemann, 1934.

Known distribution.—Wyoming.

Known stratigraphic range.—Lower Devonian.

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TENTATIVE COMPILATION OF THE MICROPALEONTOLOGY OF EGYPT

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Micropaleontological studies conducted under my direction in Egypt from 1937 to 1940, where I was ably assisted by F. G. Engelberts, in Turkey from 1940 to 1943, and again in Egypt at Fouad I University from 1947 to 1949 were based on a method of quantitative generic analysis (Tromp, 1939, 1940). The results obtained during these years have been confirmed and considerably extended recently by three Egyptian geologists, Abd el Aziz Osman (1949), Saad E. Al-Ansary (1949) and Said Omara (1951). Our method is quite different from that employed in most micropaleontological laboratories, in that no specific determinations are made. As I have received numerous inquiries concerning it, a brief explanation of the method and a summary of results may be of general interest, the more so as this article supports many of the stratigraphic statements published recently by the author (Tromp, 1951).

The principal objective of these studies was the micropaleontological recognition and classification of formations and their correlation. Only generic determinations were made for various practical reasons of which the following are particularly important.

1. The Foraminifera obtained from many samples, as from the Mesozoic rocks of the Near East, are so poorly preserved that specific identifications are very uncertain or impossible. If most of the species cannot be determined, a quantitative analysis is not possible.

2. The distribution of many species usually is considerably influenced by ecological conditions, and differences between species charts are likely to reflect only local facies conditions that are not stratigraphically significant. However, if whole genera are considered the many fluctuations of minor importance disappear.

3. In ordinary methods only reasonably abundant species are plotted graphically. A genus may be represented by numerous species none of which is common and in an ordinary species chart this would not be apparent. However, if genera as a whole are considered, characteristic frequency curves may be obtained.

4. Polymorphism is a source of much possible confusion if specific determinations must be made.

5. Foraminiferal literature is so extensive and scattered that only a few large libraries possess the publications that are necessary for accurate specific identifications. In local areas, species can be arbitrarily tagged with numbers but faunas so determined cannot be compared with the work of other paleontologists in other areas.

6. Even the most experienced micropaleontologists often disagree regarding the specific identification of similar specimens, but there is much less chance for serious divergence if determination is not carried below the generic level.

Generic abundance alone may not be sufficient to identify with desirable accuracy the age or stratigraphic position of beds

under investigation. Additional information can be obtained by noting the size of Foraminifera both in absolute terms and in ratios between different genera. The sizes of micro- and megalospheric individuals may differ but quite commonly different stratigraphic zones show different size maxima. These maxima increase or decrease in vertical sequence to form patterns that are quite characteristic.

In order to observe sizes, frequencies and ratios, samples were treated as follows:

1. A standard quantity of 200 gr. of rock was crushed to powder in a bronze mortar (this is not necessary if the material disintegrates readily) and boiled with a few spoonfuls of soda. A standard quantity of rock was used in order to obtain a uniform distribution of Foraminifera.

2. This disintegrated sample was washed over four sieves, preferably with meshes of 0.6, 0.3, 0.15, and 0.075 mm. and the residues dried.

3. The four size fractions were spread upon a picking instrument described by Scheffen (1934) and all of the specimens from two spreadings of each were picked from a circle $2\frac{1}{2}$ cm. in radius.

4. The specimens of each lot so obtained were identified generically and counted.

For best results, all of the specimens should be picked from the residues and considered, but experience has shown (Tromp, 1941) that this fraction (see 3 above) is adequate for reasonably accurate quantitative determinations. If specimens are extremely abundant in the residues, much time and labor can be saved by picking a single spreading or only a fraction of a spreading, but the number of specimens obtained must be multiplied by the proper figure to bring the product to a level comparable to the standard two spreadings.

The common percentage method used by many micropaleontologists has several distinct disadvantages of which the following should be noted particularly:

1. The abundance of specimens is likely to vary greatly in different samples. Thousands of specimens may be available in one, whereas only a few dozen may be present in others. Under these circumstances it is very difficult to obtain comparable counts.

2. The percentages obtained show only ratios but the actual abundance of specimens may be of great importance.

3. If preservation is poor, it is very difficult to identify and count specimens in a single procedure, especially from the finer sieve fractions.

4. Very low percentages, for example 20 specimens of one species among 12,000 of another, are likely to be disregarded, although the first species may be a very characteristic one.

An extensive collection of numerical data is generally very difficult to evaluate and consequently graphic presentation is desirable. Experience has shown that five frequency groups, identified by symbols, furnish a simple but effective means of indicating important faunal characters. These are: very rare (1 to 5 specimens), dots; rare (6 to 10 specimens), dashes; common (11 to 100 specimens), thin solid line; abundant (101 to 1000 specimens), medium solid line; and very abundant (more than 1000 specimens), thick solid line.

Two recent papers (Tromp, 1951a and b) describe our stratigraphic macropaleontological studies in Egypt. It is now possible with the aid of microfossils to recognize the following units in Egypt: Recent, Pleistocene, Pliocene (upper and lower), Miocene (upper, middle and lower), Oligocene, Eocene (upper, middle, lower and basal), Upper Cretaceous (Senonian, and its subdivisions upper, middle and lower Senonian, tentatively called Maestrichtian, Campanian and Santonian; Turonian and Cenomanian), Lower Cretaceous, Jurassic, and Triassic. In other parts of the Near East, e.g. Turkey, Permian and Carboniferous beds are also recognizable micropaleontologically. Micro-organisms have also been noted in the Hammammat schist, which is probably Cambrian or older (Tromp, 1951a).

Division of the Cretaceous into Upper, Middle and Lower parts, as suggested by Haug, is not possible on the basis of microfossils. Also, only three divisions of the Senonian can be made (Tromp, 1949c). Reasons for not recognizing the Danian as a stratigraphic unit have been presented elsewhere (Tromp, 1949c).

Each of the stratigraphic units listed

above is characterized by microfaunal assemblages, the most important of which are listed below (see also Tromp, 1941, 1949 c). As the section is considered from the top downward, a "first appearance" is actually a last appearance historically.

It is quite evident that several of these Near Eastern associations reflect facies conditions because many of the described genera, which disappear in Egypt at a certain stratigraphic level, have been found elsewhere in younger beds. The presence of *Gümbelina* in great numbers at the top of the Senonian and the sudden disappearance in the basal Eocene is a good example. This genus has a similar range throughout the Near East, North Africa and Italy, but in some other parts of the world it continues into the Upper Eocene. The reasons for such discrepancies are not known, but they may indicate subtle environmental differences as in pH, food supply, salinity, etc., which have left no other evidence in the sedimentary record. The absence of *Globigerina* from the middle Pliocene and younger beds in Egypt indicates the lack of open sea conditions and the abundance of Miliolidae and Peneroplidae is evidence that the water was generally shallow. Certain changes, however, seem to have a more worldwide character. They seem to record a more significant and relatively sudden alteration of conditions that can only be guessed at. The extinction of *Orbulina universa* in the Oliogocene (Tromp, 1941 and 1949b), which seems to be a universal feature, is a good example.

For the time being, the micropaleontological characteristics that distinguish the various stratigraphic units in the Near East cannot be relied upon in other areas. Correlations based on quantitative generic analysis must await the completion of studies in the neighboring regions of southeastern Europe and Asia.

RECENT

Astrorhiza and *Textularia* rare.

Miliolidae common.

Peneroplidae such as *Amphisorus*, *Marginopora*, *Peneroplis*, *Sorites* and *Spirolina* very abundant.

Amphistegina very rare, usually larger than 0.3 mm.

Elphidium common, usually larger than 0.2 mm., many species.

Rotalia calcar common, usually larger than 0.2 mm., *Eponides*, *Anomalina* and *Bolivina* absent.

Unornamented ostracods, shell fragments, etc. common.

PLEISTOCENE

Very few arenaceous forms.

Miliolidae very common.

Peneroplidae very rare to rare.

Amphistegina very rare.

Anomalina and *Bolivina* in the lower Pleistocene only, very rare, smaller than 0.2 mm.

Elphidium rare to common.

Rotalia common, larger than 0.2 mm., *Eponides* present in lower Pleistocene only.

Buliminidae, Globigerinidae and Lagenidae absent.

Neoalveolina melo present.

Non-foraminiferal micro-organisms common.

PLIOCENE

Arenaceous forms very rare.

Miliolidae very rare to rare.

Peneroplidae almost absent, only *Peneroplis* occurs.

Amphistegina rare.

Several species of *Anomalina* and *Cibicides* larger than 0.2 mm.

Several species of *Bolivina*, larger than 0.2 mm.; first appearance of *Bulimina*, larger than 0.2 mm.

Globigerinidae (missing in the Pleistocene) very rare except at base of Pliocene.

Elphidium and *Nonion* common.

Eponides and *Rotalia* (particularly *R. beccarii*) common to abundant, larger than 0.6 mm.

The marl facies of the basal Pliocene, the so-called "Intergypseous Marl Series," (Tromp, 1950a) closely resembles the Miocene. Its distinguishing micropaleontological characteristics are:

Globigerinidae very abundant, *Orbulina* common to abundant (in the middle Miocene rare to common), *Globigerina* larger than 0.3 mm. very abundant. Ratio of *Globigerinella* and *Globigerinoides* to *Globigerina* much smaller than in middle

Miocene "*Globigerina* marls" (Tromp, 1949 a).

First appearance of Lagenidae (*Nodosaria* and *Robulus*), *Hopkinsina*, *Uvigerina*, *Gyroidina*, etc.

MIOCENE

Arenaceous forms, Miliolidae and Peneroplidae almost absent.

Buliminidae common, several genera, such as *Loxostoma*, *Virgulina*, etc. first appear.

Many new families appear, such as Chilostomellidae, Cassidulinidae, etc.; among the Lagenidae several genera appear such as *Flabellina*, *Frondicularia*, *Marginulina*, etc.

Nonionidae very rare, mainly *Nonion* present.

Several rotalid genera appear such as *Cancris*, *Baggina*, *Siphonina* and *Valvulineria; Eponides* often quite abundant, *Rotalia* rare to common.

Great abundance of Globigerinidae, particularly *Globigerinoides*. Sometimes 24% of the rock volume is composed of Globigerinidae.

DIFFERENCES BETWEEN UPPER, MIDDLE AND LOWER MIOCENE

Globigerina usually less than 2000 in lower Miocene, more than 5000 in marly facies of middle and upper Miocene, representing about 40% of all Globigerinidae in the lower Miocene, 60–90% in the middle and upper Miocene.

Globigerinella most abundant in lower Miocene, 20–30% of total Globigerinidae, less than 20% in middle and upper Miocene.

Globigerinoides dominant (in numbers, not in percentages) in middle Miocene; in lower Miocene 25–40% of whole fauna; in middle Miocene 7–20%, mostly more than 15%; in upper Miocene 4–15%, mostly less than 10%. *Globigerinoides* decreasing less rapidly than *Globigerinella* (from lower to upper Miocene), as a result number of *Globigerinoides* usually dominant compared with *Globigerinella*.

Orbulina usually less than 1% of all Globigerinidae except at top of upper Miocene and in basal Pliocene where percentage is larger.

Globorotalia, smaller than 0.2 mm. very rare, in lower Miocene only.

Amphistegina restricted to upper Miocene, at least in argillaceous sections.

Operculina complanata var. *heterostegina* characteristic for middle Miocene limestone.

Miogypsina, lepidocyclines, such as *Eulepidina*, *Lepidocyclina s.s.* and *Nephrolepidina*, and *Spiroclypeus* characteristic for lower Miocene limestone at Risan Aneiza (N.E. Sinai).

OLIGOCENE

The Oligocene of Egypt usually is developed in a fluviomarine or continental facies and is not richly fossiliferous. In the few marine marl sections (e.g. near Wadi Dara along the west coast of the Gulf of Suez) it is characterized as follows:

Globigerinidae abundant; *Globigerinoides* rare; *Orbulina* absent (Tromp, 1941, 1949b).

Globorotalia very rare, smaller than 0.2 mm.

In limestone small *Camerinae*, few *Spiroclypeus*, *Cycloclypeus*, *Miogypsina* and *Lepidocyclina* are present.

UPPER EOCENE

Globigerina common to abundant, *Globigerinella* usually rare, *Globigerinoides* and *Orbulina* absent.

Bolivina very abundant and smaller than 0.2 mm. at some localities (e.g. Wadi Tayiba, east coast of Gulf of Suez); *Bulimina* and *Uvigerina* abundant and larger than 0.3 mm.

Gümbelina common, smaller than 0.2 mm.

Globorotalia very rare, with sharp keels, smaller than 0.2 mm.; specimens resembling *Globigerinella*, often abundant, larger than 0.3 mm.

Larger Foraminifera, such as small *Camerina*, *Heterostegina*, *Operculina* and *Discocyclina* occur in limestone.

MIDDLE EOCENE

Globigerina common in upper part, abundant or very abundant in lower part; *Globigerinella* practically missing; *Globigerinoides* and *Orbulina* missing.

Gümbelina usually missing, smaller than 0.2 mm.

Globorotalia very rare, smaller than 0.2 mm.

Larger Foraminifera, such as *Discocyclina*, *Fasciolites*, large *Camerina*, *Orbitolites*, *Assilina* and *Dictyoconus*, occur in limestone.

LOWER EOCENE

Globigerina very abundant; *Globigerinella* practically missing except in basal Eocene where specimens are common to abundant; *Globigerinoides* and *Orbulina* missing.

Gümbelina very rare except near the base of lower Eocene where they are rare to common and smaller than 0.2 mm.

Globorotalia rare, except near the base, where they are very abundant.

Larger Foraminifera occur in the limestone facies of lower Eocene, *Operculina*, *Fasciolites* (mainly in upper part of lower Eocene) and very large *Camerina*.

SENONIAN-BASAL EOCENE BOUNDARY

In the Middle East, the uppermost Cretaceous and lower Eocene are transitional (Tromp, 1941, 1949c). There are two facies (Tromp, 1943a): One, the "Anatolian facies," occurs in Turkey as far as the Syrian border and is composed of grey marls, not very rich in microfossils. The other, the "Arabian or chalky facies" is composed of white chalk or chalky marl rich in Foraminifera. This is developed in Syria, Iraq, Palestine and Egypt. The Cretaceous-Eocene boundary in Egypt is marked by the following micro-faunal associations which seem to be characteristic of the greater part of the Middle East and North Africa:

Gümbelina very abundant in uppermost Cretaceous, many larger than 0.3 mm.; rare to common in basal Eocene, smaller than 0.2 mm.

Globorotalia suddenly becomes very abundant in basal Eocene, mostly sharply keeled, *G. simulatilis* (Schwager) and *G. velascoensis* (Cushman).

Globigerina much more abundant than *Globigerinella* in basal Eocene; in uppermost Cretaceous, they are about equal, and in the Campanian of Arabian facies, *Globigerinella* generally dominates.

Globotruncana abundant or very abundant in uppermost Cretaceous, absent in Eocene.

Such genera as *Pseudotextularia* and *Bolivinoides* occur in the Cretaceous with *Bolivina incrassata* (Reuss), *Gaudryina rugosa* (D'Orbigny), *Anomalina ammonoides* (Reuss). Exceptionally *Eouvigerina*, *Gümbelitria*, *Ventilabrella* and *Neobulimina* also are present.

Typically Tertiary foraminifers, such as *Uvigerina*, *Orbulina*, *Globigerinoides*, etc. are missing from upper Senonian faunas even in samples with very great abundance of forms. *Bulimina*, if present, smaller than 0.2 mm.

The Senonian is rich in Valvulinidae and Verneuilinidae, Lagenidae, Rotaliidae (*Eponides*, *Rotalia* and *Gyroidina*), non-foraminiferal micro-organisms, particularly highly ornamented ostracods, fish-teeth and coproliths.

The top of the Cretaceous is known in the Middle East as the *Globotruncana-Gümbelina* zone; basal Eocene is recognized as the *Globigerina-Globorotalia* zone.

SENONIAN-TURONIAN BOUNDARY

Valvulinidae and Verneuilinidae missing or extremely rare in Turonian but common in Senonian; only *Rhabdammina* seems to be common in Turonian, at least in northeast Sinai.

Anomalina more abundant in the Senonian; *Bolivina* common in Senonian but very rare in Turonian.

Globigerina and *Globigerinella* rare in Turonian, common to abundant in Senonian.

Globorotalia very rare in Turonian, rare to common in basal Senonian.

Globotruncana very rare in Turonian, common in Senonian.

Bolivinella, *Bolivinoides*, *Ventilabrella*, etc. characteristic of Senonian but missing in Turonian.

Gümbelina rare in both basal Senonian and Turonian, but common to abundant in upper Senonian.

Rotaliidae rare in Senonian, *Rotalia* seem to be entirely absent.

Larger Foraminifera occur in Turonian limestone: *Orbitolina*, particularly in middle and lower Turonian; *Dicyclina* and *Cuneolina* (in Turkey); *Omphalocyclus* and *Orbitoides* in both upper Turonian and basal Senonian (of Turkey).

MAESTRICHTIAN, CAMPANIAN AND SANTONIAN COMPARED

In Maestrichtian, *Globigerina* usually equal to or slightly more abundant than *Globigerinella*, *Gümbelina* abundant, commonly larger than 0.3 mm.; also rich in other Heterohelicidae (*Bolivinoides*, *Pseudotextularia*, etc.) and arenaceous forms (Valvulinidae and Verneuilinidae).

In Campanian, *Globigerinella* very abundant, *Globigerina* abundant, *Gümbelina* common, other Heterohelicidae less common than in Maestrichtian, *Globorotalia* common in both.

In Santonian, *Globigerinella* dominant; *Gümbelina*, *Globorotalia*, and arenaceous forms rare, *Globotruncana* usually rare.

TURONIAN-CENOMANIAN BOUNDARY

Cenomanian rich in arenaceous forms, particularly Lituolidae,

Trochamminidae; Valvulinidae and Verneuilinidae few or absent.

Anomalina common in the Turonian but very rare in Cenomanian.

Bolivina very rare near top of Cenomanian but otherwise practically missing; *Bulimina*, smaller than 0.2 mm., common in Turonian, very rare in Cenomanian.

Globigerina and *Globigerinella* very rare in Cenomanian, smaller than 0.2 mm.

Gümbelina and *Globotruncana* usually missing from Cenomanian.

Globorotalia very rare in Cenomanian.

Rotaliidae missing or extremely rare in Cenomanian.

Ostracods common to abundant in Cenomanian.

CENOMANIAN-LOWER CRETACEOUS BOUNDARY

Lower Cretaceous poor in arenaceous forms.

Miliolidae very rare in Cenomanian, missing in Lower Cretaceous.

Anomalinidae and Buliminidae missing in Lower Cretaceous.

Globigerina and *Globigerinella* very rare in Lower Cretaceous, smaller than 0.2 mm.

LOWER CRETACEOUS-JURASSIC BOUNDARY

Cornuspira, smaller than 0.2 mm. occurs in Jurassic but apparently absent in Cretaceous.

Globigerinidae missing in Jurassic; Anomalinidae and Buliminidae absent from both Lower Cretaceous and Jurassic.

Globorotalia very rare in Lower Cretaceous, absent in Jurassic.

Lagenidae, usually smaller than 0.2 mm., common in Jurassic.

Eponides, smaller than 0.3 mm., common in Upper Jurassic.

Ostracods, fish-teeth and echinoid spines very common in Jurassic.

TRIASSIC AND CARBONIFEROUS

The Triassic seems to be without Foraminifera, but D. B. Eicher discovered in 1945 at Araif el Naga in northeast Sinai beds containing conodonts and a macroscopic Middle Triassic fauna (Eicher, 1947). This is particularly interesting because conodonts have usually been considered Paleozoic index fossils. In 1940, Eicher discovered conodonts in Carboniferous clay-slates from the Ras Gharib oil fields on the west coast of the Gulf of Suez. These are extremely small and fragmentary, but the Triassic specimens are more diverse and abundant. Lack of sufficient literature prevented Eicher at the time from making generic determinations. Further microfaunal studies of the Carboniferous surface and subsurface sections of Egypt may reveal the presence of other characteristic microfossils.

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A NEW EOCENE RADIOLARIAN GENUS[1]

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In the course of an examination of Eocene radiolarian faunas of the Mount Diablo area, California, Clark and Campbell (1942) found a few specimens of a form which was described as *Soreuma* (*Soreumium*) *magnificum* Clark and Campbell. Later, an investigation of the Radiolaria from the Kreyenhagen formation (Clark and Campbell, 1945) provided more specimens, and as these latter were better preserved than those from the former locality, and all had radial spines, the subgeneric designation was emended to *Soreumidium*.

A re-examination of specimens from the Kreyenhagen near Los Banos (Locality A 3980, University of California Museum of Paleontology) has shown that this form is not a *Soreuma*, but a dicyrtid Nassellarian for which a new genus must be erected. This work has been made possible through financial aid from the Penrose Bequest of the Geological Society of America.

The distinguishing feature of the genus, and the feature which caused the confusion with *Soreuma*, is the presence of a velum on the under side of the flatly expanded thorax. In the species from the Kreyenhagen formation, this velum is spongy, and underlies a considerable area of the thoracic wall. A related form, to be described in a subsequent paper, has been found in an upper Eocene sediment from the continental slope off New Jersey: the velum in this species is not spongy, but consists of a short, porous, cylindrical tube.

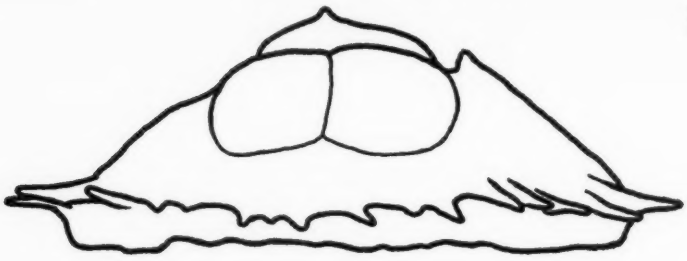
The following description is based entirely on specimens from the Kreyenhagen formation near Los Banos, from Locality A 3980 of the University of California Museum of Paleontology. The specimen figured in figure 1 could not be mounted successfully after drawing, but the other two figured specimens are deposited in the collections of the University of California Museum of Paleontology. The systematic classification is based on Haeckel's general system, with the emendations necessitated by the Code of Zoological Nomenclature.

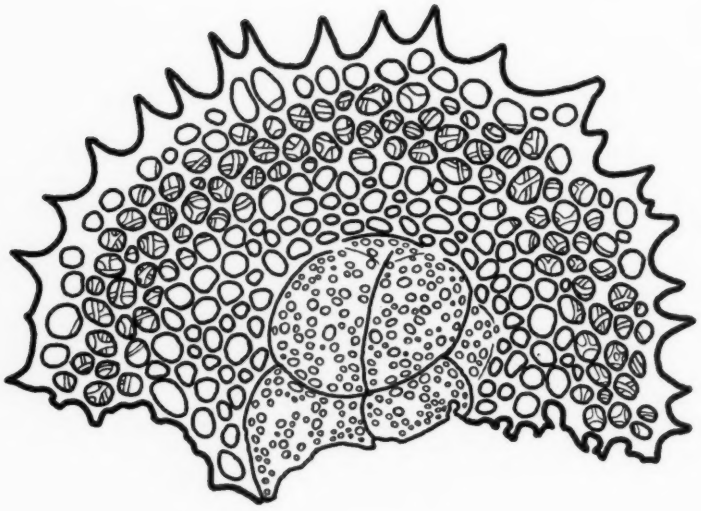
Family SETHOPHORMIDIDAE

Tribe *Sethophormida* HAECKEL, 1882, Jenaische Zeitschr. f. Naturw., 15: 432; 1887, Chall. Repts., Zool., 18 (2): 1243.
Family *Anthocyrtida* HAECKEL, 1887, Chall. Repts., Zool., 18 (2): 1241–1242.
Family *Sethophormidae* HAECKEL. Frizzell and Middour, 1951, Bull. Univ. Missouri School of Mines and Metallurgy, Tech. Ser., 77: 29.

Dicyrtida multiradiata. Cyrtoidea with a two-jointed shell, divided by a transverse constriction into cephalis and thorax, and bearing numerous—four to nine or more—radial apophyses.

[1] Contribution from the Scripps Institution of Oceanography, New Series, No. 575.





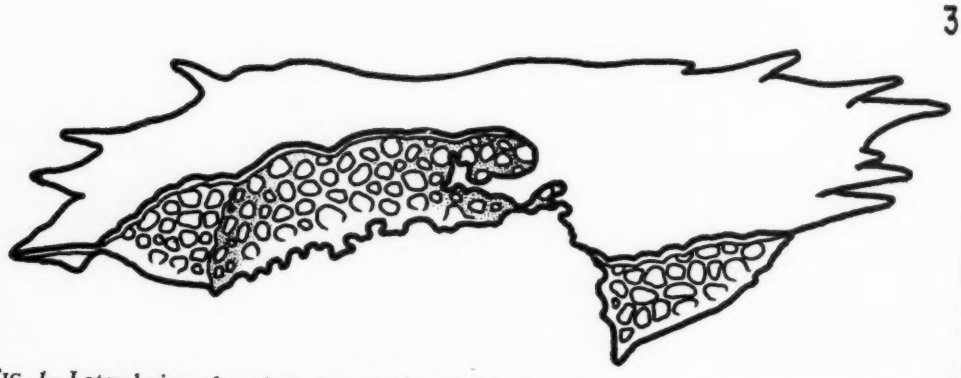


FIG. *1*—Lateral view of a relatively small individual, showing the relations of the lobed cephalis, the expanded thorax, and the velum. Part of one of the cephalic lobes is broken away. ×330.
FIG. *2*—A broken test viewed from above, illustrating the nature of the pores of the cephalis and thorax. ×330.
FIG. *3*—Part of the thorax and velum, viewed laterally. ×330.

The family name is here emended to its correct derivation from the Greek genitive.

Subfamily SETHOPHORMIDINAE

Sethophormida HAECKEL (in part), 1882, Jenaische Zeitschr. f. Naturw., 15: 432; 1887, Chall. Repts., Zool., 18 (2): 1243.
Sethophorminae HAECKEL. Clark and Campbell, 1942, Geol. Soc. Amer., Sp. Pap., 39: 72.

Sethophormididae with the basal mouth of the shell open.

The subfamily name is here emended to its derivation from the Greek genitive.

Genus VELICUCULLUS Riedel and Campbell, n. gen.

Sethophormidinae with a spongy or lamellar velum on the oral surface of the broadly campanulate or almost discoidal thorax. Cephalis of several lobes.

Type species.—*Soreuma magnificum* Clark and Campbell, 1942.

This genus differs from all others of the subfamily in having a velum, which is quite a different structure from the separate peristome found in *Anthocyrtidium*. The peristome of *Anthocyrtidium* is probably homologous with the spine-bearing edge of this new genus.

VELICUCULLUS MAGNIFICUS (Clark and Campbell, 1942)

Soreuma (*Soreumium ?*) *magnificum* CLARK and CAMPBELL, 1942, Geol. Soc. Amer., Sp. Pap., 39: 51–52, pl. 4, fig. 15.
Soreuma (*Soreumidium*) *magnificum* CLARK and CAMPBELL. Clark and Campbell, 1945, Geol. Soc. Amer., Mem. 10: 28, pl. 5, fig. 2.

Campanulate shell greatly flattened, almost discoidal, especially as the cephalis is lost from most specimens. Cephalis delicate, with usually three or four lobes separated by distinct sulci, and 150–200 small circular pores scattered over the surface. Thorax greatly expanded, almost flat, with slightly rough surface: pores subcircular, as broad, to three times as broad, as the intervening bars, 6–10 in a vertical series, 22–27 on the half-circumference, arranged in indefinite vertical series, decreasing a little in size from the aperture towards the cephalic suture. 25–30 tooth-shaped radial apophyses on the margin of the thorax, not all exactly in one plane, generally extending almost horizontally. Occasionally, the bases of the larger radial apophyses are reticulated. Spongy velum on the lower surface of the thorax, extending inward from the bases of the radial apophyses, its width approximately 0.3 of the radius of the shell. Diameter of shell 300–350 μ, of thoracic pores 5–10 μ. Length of radial apophyses 50–30 μ. Width of cephalis 130–150 μ, its height 30–50 μ. Width of velum 35–50 μ.

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NOTE ON THE CRETACEOUS-TERTIARY BOUNDARY IN TRINIDAD, B.W.I.

With remarks on the problem of the determination of some Paleocene Globorotaliae

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INTRODUCTION

The determination of the Cretaceous-Tertiary boundary in Trinidad, B.W.I., has in recent years given rise to controversies. The principal point of disagreement lies in the age interpretation of the Lizard Springs formation to which some paleontologists assign an early Tertiary (Paleocene-lower Eocene), others an Upper Cretaceous age.

Several papers have been published on the Lizard Springs foraminiferal fauna by Cushman and co-authors, who consider its age to be Upper Cretaceous and compare it with that of the Velasco shales. In 1942

(p. 531) H. H. Renz, without offering faunistic evidence, suggested a ?Maestrichtian to Lower Paleocene age for the Lizard Springs formation. In 1946, the age of the Lizard Springs formation was discussed at some length by Cushman and Renz. Although they recorded no such typical Upper Cretaceous foraminiferal genera as *Globotruncana*, they attempted to demonstrate the Cretaceous character of the fauna by comparing it quantitatively with the faunas of over-and underlying beds. Other fossil evidence supporting a Paleocene-lower Eocene age, such as larger Foraminifera were not considered to be of decisive value. Globigerinae, now recognized as excellent stratigraphic markers, were not discussed. Cushman (1946) considered the Lizard Springs and the Velasco faunas to be contemporaneous with some of the Upper Cretaceous from the Gulf Coastal region.

Grimsdale (1947) in a note on above expressed the opinion that the Lizard Springs formation and the Velasco shales are of early Tertiary (Paleocene and lower Eocene) age.

Cushman (1947) in a reply to Grimsdale maintained an Upper Cretaceous age for the Lizard Springs formation.

Bolli (1950) in a study of the direction of coiling of various Globorotaliidae preferred a Paleocene age for the Lizard Springs formation. This was commented on by H. H. Renz (1951) in a note in which he stressed again the Upper Cretaceous age of the Lizard Springs fauna. In the same note he also questioned the correctness of some of the writer's *Globorotalia* determinations. This point will be discussed in the second part of the present note.

THE CRETACEOUS-TERTIARY BOUNDARY

Recent geologic field observations and paleontologic studies of various well sections permit a revision of the stratigraphy of the Upper Cretaceous and lower Tertiary beds. On the basis of new evidence contributed by Mr. K. W. Barr, Drs. P. Bronnimann, H. G. Kugler, K. Rohr, H. H. Suter and the writer, a definite lithologic and faunistic boundary between the Upper Cretaceous and the Tertiary can be established. This boundary agrees well with that accepted for other regions, e.g., the Near East (Tromp, 1949) and Texas (Plummer, 1926).

Former Interpretation of the Upper Cretaceous-Lower Tertiary Sequence in Trinidad by Cushman and Renz

Cushman and Renz considered the Navet formation as ?Paleocene, lower and middle Eocene (1948). The neritic Soldado formation was determined as Paleocene (Midway) (1942), and as such was assumed to represent locally the basal part of the Navet formation (1948). The Lizard Springs formation was regarded as late Maestrichtian-Danian, conformably underlain by the Chaudière and Tarouba formations, and grading upwards into the Navet formation. Thus the Lizard Springs formation would occupy a transitional position between late Cretaceous and early Tertiary (1946). Based on faunistic evidence, the Lizard Springs formation was divided into a lower and upper zone.

The Chaudière and Tarouba formations were considered to be approximate time equivalents. The Tarouba formation was divided into a lower ("argiline") and an upper (shale) member of transitional relationship (Renz 1942, p. 528). The "Pointe-à-Pierre Railway Cut marl" and the "Lantern marl" were thought to be interbedded in the probably lower part of the Chaudière shale (1942, 1947).

Based on above interpretations, the Upper Cretaceous-Tertiary boundary falls between the Lizard Springs formation and the Navet formation. Since there are known transitions between these formations, this boundary line is often indistinct.

Present Interpretation of the Upper Cretaceous-Lower Tertiary Sequence in Trinidad

Age interpretation.—The occurrence of a conglomerate and boulder bed (St. Joseph boulder bed, described by K. W. Barr in a private report) within this sequence is probably the most important new feature. It was first found in the San Fernando area, where it divides the Chaudière formation (in this area formerly called "upper Tarouba") from the underlying Naparima

Hill formation (formerly called "argiline" or "lower Tarouba"). Subsequently, the St. Joseph boulder bed was encountered in the same stratigraphic position in well sections of South Trinidad. The St. Joseph boulder bed, which can be of considerable thickness, implies a stratigraphic break.

For these reasons the "Pointe-à-Pierre Railway Cut marl" cannot be maintained any longer as evidence for the age of the Chaudière formation and it has to be discarded as a biostratigraphic unit.

Based on recent checks of the outcrop of the "Lantern marl" this is either a slipmass

TABLE 1.—PRESENT INTERPRETATION OF THE UPPER CRETACEOUS-LOWER TERTIARY SEQUENCE IN TRINIDAD, B.W.I.

LOWER TERTIARY	MIDDLE-LOWER EOCENE	NAVET FORMATION / RAMDAT MARL		Paleocene-Eocene Globorotaliae	
	PALEOCENE	CHAUDIÈRE FORMATION	LIZARD SPRINGS FORMATION: UPPER	Paleocene-Eocene Globigerinae	
			LIZARD SPRINGS FORMATION: LOWER / SOLDADO FORMATION		
		UNCONFORMITY: ST. JOSEPH BOULDER BED			
UPPER CRETACEOUS	MAESTRICHTIAN—TURONIAN	GUAYAGUAYARE BEDS / NAPARIMA HILL FORMATION		Gümbelinae	Globotruncanae; Upper Cretaceous Globigerinae
		UNNAMED SHALES			
	CENOMANIAN	GAUTIER FORMATION			

The main support for an Upper Cretaceous age of the Chaudière formation was found by Cushman and Renz in the *Globotruncana*-bearing faunas of their "interbedded" "Pointe-à-Pierre Railway Cut marl" and "Lantern marl" (1947).

On close geologic and paleontologic reexamination of the "Pointe-à-Pierre Railway Cut marl" at its type locality, it was found to be a heterogeneous alien slipmass of what are now known as Guayaguayare beds, mixed with some older material (Aptian-Albian).

The gray calcareous shales of the Guayaguayare beds (subsurface section, Guayaguayare area, Bolli, 1951) are found to overlie the Naparima Hill formation in various subsurface sections and are faunistically well defined by a characteristic *Globotruncana* fauna which so far can be divided into three distinct faunistic units. These are from top to bottom: *G. mayaroensis*, *G. gansseri* zones and *G. lapparenti tricarinata* subzone. Globotruncanae characteristic for all three zones were found in the blocks of the "Pointe-à-Pierre Railway Cut marl."

alien to the Chaudière formation or a small tectonic wedge. The *Globotruncana* fauna of the "Lantern marl" (Bolli, 1951) belongs either in the *Globotruncana gansseri* zone, or is possibly transitional between this zone and the underlying *G. lapparenti tricarinata* subzone.

Recent observations from wells furthermore show that in places the calcareous Lizard Springs formation with its typical fauna is interbedded with purely arenaceous faunas indistinguishable from those of the Chaudière formation. The contemporaneity of the Chaudière and Lizard Springs formations is thus well established. The subdivision of the Lizard Springs formation into an upper and lower zone is discussed in the second part of this note.

The *Globorotalia* and *Globigerina* fauna of the Soldado formation is closely related to that of the lower zone of the Lizard Springs formation (see tables 1 and 2).

Remarks on pelagic Foraminifera.—Little attention was paid by Cushman and Renz to the pelagic Foraminifera of the Upper Cretaceous and lower Tertiary. Taking

account of this fauna, one is faced with a total change in pelagic species from the Upper Cretaceous to the Paleocene.

The genus *Globotruncana*, characteristic for the Upper Cretaceous, does not occur in the Lizard Springs formation and on the other hand none of the typical lower Tertiary representatives of the genus *Globorotalia* are found in the Upper Cretaceous.

The characteristic Upper Cretaceous Globigerinae (e.g., rugose types) are followed in the Lizard Springs formation by Globigerinae of different morphologic aspect and rules of coiling. The numerous *Gümbelina* species with their abundance in specimens in the Upper Cretaceous are reduced in the Lizard Springs formation to one relatively scarce species only, which in addition seems to be different from the Upper Cretaceous forms.

Conclusions.—Observations indicating a clear separation of the Upper Cretaceous Guayaguayare beds and Naparima Hill formation from the lower Tertiary Chaudière-Lizard Springs-Soldado formations are:

(1) The occurrence of a boulder bed at the base of the Chaudière-Lizard Springs formations.
(2) The elimination of the *Globotruncana*-bearing "Pointe-à-Pierre Railway Cut marl" and the "Lantern marl" as age indicators for the Chaudière formation.
(3) The marked difference between the pelagic faunas of the Upper Cretaceous and the lower Tertiary.

REMARKS ON THE DETERMINATION OF SOME PALEOCENE GLOBOROTALIAE

In his note, H. H. Renz (1951, p. 15) criticizes a number of species and variety determinations of the genus *Globorotalia*, which were considered by the writer (1950) to be of Lizard Springs (Paleocene) age. In order to clarify this criticism a collection of the Globorotaliae in question from the type locality samples of the lower zone of the Lizard Springs formation (Rz. 283, 286–291[1]; see Cushman and Renz, 1946, p. 5); the upper zone of the Lizard Springs formation (Rz. 281–282, 284–285, 292–296; see Cushman and Renz, 1946, p. 7); the Soldado formation (K. 2950; see Cushman and Renz, 1942, p. 1); and the Ramdat marl (basal part of the Navet formation; Rz. 413; see Cushman and Renz, 1948, pp. 1-3) were sent to Miss R. Todd[2] of the U. S. National Museum, Washington, for comparison with the holo- or paratypes of the Cushman Collection.

H. H. Renz believes that the writer mistook *Globorotalia aragonensis* Nuttall, which in his opinion does not occur in the Lizard Springs formation, for *Globorotalia velascoensis* (Cushman). Based on our observations, both of these species occur not only in a number of samples of the upper zone of the Lizard Springs formation (Rz. 281, 293, 295, 296), but also in the Ramdat marl (Rz. 413). This has been confirmed in the case of *G. velascoensis* by Miss Todd. As far as *G. aragonensis* (described by Cushman and Renz, 1948, from the Ramdat marl) is concerned, Miss Todd believes however, that the specimens of the Ramdat marl and of the Lizard Springs formation do not agree with the paratypes of the Cushman Collection. The following is a comparison of Miss Todd's observations on the paratype material and of Cushman and Bermudez' notes on Cuban material of this species (1949) with Nuttall's original description of *G. aragonensis* (1930). According to Nuttall the umbilicus of *G. aragonensis* is *narrow* and deep, whereas Miss Todd mentions it as being *widely open* and deep, Cushman and Bermudez describe it as *large open*. Nuttall describes the border as subacute, sometimes slightly lobulate with narrow peripheral beading; Miss Todd as smooth, not lobulated, not beaded nor flanged; Cushman and Bermudez as acute and keeled, sometimes slightly spinose. Nuttall describes the sutures as limbate, Cushman and Bermudez as indistinct, except the last few on the ventral side. Judging from such discrepancies it appears probable that the paratypes of *G. aragonensis* in the Cushman Collection are not identical with the holotype.

[1] Rz. sample numbers refer to samples in the Collections of Trinidad Leaseholds Ltd.

[2] The writer is indebted to Miss R. Todd for kindly carrying out these comparisons and for the permission to make use of her notes (letter of June 4, 1951).

In his type description of *G. aragonensis* Nuttall adds: "It is likely to be confused with *G. velascoensis* but differs from typical specimens of the latter in having a *smaller umbilicus*, a smaller number of chambers in the last whorl and a more elevated dorsal surface." These features agree well with our specimens from the Ramdat marl and the upper zone of Lizard Springs formation.

Grimsdale (1951) pointed out that some of Cushman's figures of *G. velascoensis* represent another species (e.g., Cushman and Jarvis, 1932, pl. 15, figs. 8a–c; Cushman, 1946, pl. 63, figs. 6a–c). These figures show a distinct spinose type with less chambers than the original *G. velascoensis* and thus might be attributed to *Globorotalia lacerti* Cushman and Renz. The figures of the holotype of *G. lacerti* (Cushman and Renz, 1946, pl. 8, figs. 11, 12) are poor reproductions however and do not permit reliable verification.

The two species *G. aragonensis* and *G. velascoensis* are doubtless closely related. Intermediate specimens which cannot be assigned with certainty to either of the two species are found in both the upper zone of the Lizard Springs formation and the Ramdat marl. *G. velascoensis* is more frequent in the upper zone of the Lizard Springs formation and less in the Ramdat marl compared with *G. aragonensis*. This might indicate that *G. velascoensis* is an ancestral form of *G. aragonensis*, that occurs together with the latter in the upper zone of the Lizard Springs formation and at least part of the Eocene Navet formation. *G. velascoensis* does not occur in the lower zone of the Lizard Springs formation. This seems to agree with the findings of Grimsdale (1951), who did not observe this species in the lowermost Velasco.

Globorotalia wilcoxensis var. *acuta* Toulmin is another species determination questioned by H. H. Renz. Representatives of this species from Lizard Springs type locality samples (Rz. 282–292, 294–295) and the Soldado type locality (K. 2950) were compared by Miss Todd with paratypes of the Cushman Collection. Although the specimens from the Soldado locality were described and figured by Cushman and Renz (1942, pl. 3, figs. 2a–c) as *G. wilcoxensis* var. *acuta*, Miss Todd comes to the following conclusion: "I believe these are not the same as the specimens from the Wilcox Eocene of Alabama. Paratypes are not very strongly lobulate around the periphery and the sutures are very indistinct on the dorsal side and not at all beaded." Miss Todd's observations again do not fully agree with the original variety description. Toulmin (1941) observes a strongly lobulate periphery, bounded by a thick flange, and describes the sutures as distinct and limbate on the dorsal side.

The examined Soldado and the Lizard Springs specimens are identical. Thus, assuming Cushman and Renz' determination of *G. wilcoxensis* var. *acuta* in the Soldado formation as being correct, the same variety would also occur in the above mentioned Lizard Springs type locality samples.

The sizes (largest diameter) of both the Soldado and Lizard Springs specimens are very uniform and vary between 0.35 and 0.40 mm., which is a little less than the measurement given for the holotype (0.46 mm.). The number of chambers in the last whorl of the Trinidad specimens, as well as the other features, agree well with Toulmin's description of *G. wilcoxensis* var. *acuta*.

From a taxonomic point of view, it is probably not correct to regard *acuta* as a variety of *G. wilcoxensis*. Together with *Globorotalia crassata*, *crassata* var. *aequa*, *lacerti*, and *spinulosa*, *G. wilcoxensis* apparently belongs to the characteristic group of strongly spinose Eocene-Paleocene Globorotaliae. At least some of these species distinctly prefer dextral coiling. *G. wilcoxensis* var. *acuta* appears to be closer related to the *G. aragonensis-G. velascoensis* group, which is less spinose and apparently prefers a sinistral direction of coiling (Bolli, 1950).

Toulmin (1941) states: "*G. wilcoxensis* var. *acuta* resembles *G. velascoensis* but differs from that species in having only 4 or 5 chambers in the final whorl, instead of 7 and the sutures are not beaded in the Alabama variety." Grimsdale (1951) regards the *acuta* as variety of *G. velascoensis*. It is possibly an ancestral form of *G. velascoensis*.

A third *Globorotalia* determination from the Lizard Springs formation questioned by

H. H. Renz is that of *Globorotalia crassata* var. *aequa* Cushman and Renz. This variety was originally described by Cushman and Renz (1942) from the Soldado formation. In his remarks, H. H. Renz (1951) would prefer to assign the variety cited from the lower zone of the Lizard Springs formation to *Globorotalia lacerti*. He characterizes *G. lacerti* as follows: "This species can be distinguished from *G. crassata aequa* by its coarser spinose ornamentation and its indistinct sutures on the dorsal side, which are however rather well pronounced in *G. crassa aequa*. *G. lacerti* may be an ancestral form of *G. crassata aequa*." In the type description of *G. lacerti* by Cushman and Renz (1946), spines are characterized as follows: "wall finely but distinctly spinose, with very short spines."

Specimens from type locality samples of the Soldado formation (K. 2950) and the Lizard Springs formation (Rz. 282–292, 294–295), believed by the writer to be identical with *G. crassata* var. *aequa*, were compared by Miss Todd with the original types of the Cushman Collection. Her observations are: "These do not all seem entirely typical to me, although those from the Soldado formation are closer to the paratypes. Those from the Lizard Springs are slightly more coarsely spinose. I would consider these closer to *G. lacerti* Cushman and Renz." This would in general agree with H. H. Renz, who also sees the specific difference in the size of the spines.

The writer could, however, not recognize any such difference in spines or pronunciation of sutures in the Soldado and Lizard Springs specimens. To prove whether it is possible or not to recognize such differences in size of spines as claimed by H. H. Renz,

TABLE 2.—DISTRIBUTION OF THE DISCUSSED GLOBOROTALIAE IN THE INVESTIGATED TYPE LOCALITY SAMPLES OF THE RAMDAT MARL (NAVET FORMATION), LIZARD SPRINGS FORMATION AND SOLDADO FORMATION

Type locality samples	*G. aragonensis*	*G. velascoensis*	*G. wilcoxensis* var. *acuta*	*G. crassata* var. *aequa*
Ramdat marl (Navet formation) Rz. 413	×	×		
Lizard Springs formation Upper zone Rz. 281, 292, 293, 296	×	×		
Rz. 295 (?Heterogeneous sample)	×	×	×	×
Lizard Springs formation Lower zone Rz. 282, 284, 285, 294			×	×
Rz. 283, 286–291			×	×
Soldado formation K. 2950			×	×

* Boundary line between upper and lower zone of the Lizard Springs formation after Cushman and Renz.

the number of spines per 100μ of six Soldado and six Lizard Springs specimens were counted and the following results obtained:

Soldado 6;5;5;5;5;5 Spines per 100μ
Lizard Springs 6;5;5;5;6;5–6 Spines per 100μ

In addition to this very even distribution of the spines in all the examined cases, no measurable difference in size of the single spines was observed. A specific differentiation based on spine sizes of the above Lizard Springs and Soldado specimens is thus in the writer's opinion not practicable. Further evidence that the Soldado and Lizard Springs specimens under discussion

belong to the same species, is the fact that their average size of 0.35–0.4 mm. (extremes 0.3, 0.45 mm.) is in good agreement with the holotype (0.4 mm.), but differs strongly from *G. lacerti* which sizes according to its authors "up to 0.65 mm." From available information, *G. crassata* var. *aequa* always occurs together with *G. wilcoxensis* var. *acuta*, this not only in the Soldado but also in the examined Lizard Springs samples.

The distribution of the discussed Globorotaliae (table 2) strongly suggests that a part of Cushman and Renz' "upper zone of the Lizard Springs formation" (Rz. 282, 284, 285, 294) is of the same age as the samples attributed by these authors (1946) to the "lower zone of the Lizard Springs formation." The Soldado formation considered by Cushman and Renz to be on top of the Lizard Springs formation, is in fact an age equivalent of the lower zone of the Lizard Springs formation.

The Lizard Springs beds at their type locality are a part of a tectonic wedge. They are over- and underlain by imbricated Oligocene. The only sample (Rz. 295) containing both *G. aragonensis/G. velascoensis* together with *G. crassata* var. *aequa/G. wilcoxensis* var. *acuta* has therefore to be regarded with a certain amount of suspicion. It does not necessarily represent a homogeneous assemblage. A distinct age difference can be assumed between the *G. wilcoxensis* var. *acuta-G. crassata* var. *aequa*-bearing beds and those with *G. aragonensis-G. velascoensis;* the latter possibly representing already lower Eocene. To verify this, a thorough investigation of the remaining *Globorotalia* species and Globigerinae would have to be carried out.

CONCLUSION

In view of above facts, the writer has no cause to alter the determinations of *G. aragonensis*, *G. wilcoxensis* var. *acuta*, and *G. crassata* var. *aequa* doubted by H. H. Renz (1951).

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ON *ASTERIGERINA GÜRICHI* (FRANKE)

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In a recent note on *Asterigerina gürichi* (Franke) and remarks on polymorphism and the stratigraphic use of Foraminifera, J. Hofker (1948) analyzed *Asterigerina gürichi* and two species recognized by ten Dam and Reinhold (1942) as *Asterigerina staeschei* and *Asterigerina frankei* and came to the conclusion that these three species are actually the three generations of a single species and constitute a typical example of trimorphism in fossil Foraminifera.

Even for Recent forms, where living specimens may be studied in great quantities, it is often impossible to prove trimorphism and J. Le Calvez (1938) proved on experimental grounds that several species of Foraminifera show dimorphism but no evidence of trimorphism. It seems that Hofker has applied his principle of trimorphism far too rigorously and often without even the least embryologic or cytologic proofs. Certainly fossil Foraminifera are far more difficult to deal with and it may be impossible to prove that one has to do with a single real population of a certain species and that the different, apparently related, forms belong to one species only. In his conclusions, Le Calvez (1938) stated that although accepting provisionally with the greatest tolerance all Hofker's contentions regarding trimorphism in recent Foraminifera, his results prove that the principle of morphological and embryological trimorphism is by no means applicable to other species and that it seems rather daring to require that no species should be named without knowing its three generations, a requirement which seems preposterous for many fossil Foraminifera. These contradictions show that one cannot conclude that the life-cycle of a polymorphous group such as the Foraminifera is defined by a narrow and strict law and that one cannot accept the existence of trimorphism within any species without discussion. One is even entitled to distrust a strictly morphological analysis of populations of empty tests, even of Recent Foraminifera, as proven by the work of Le Calvez.

In the case of *Asterigerina gürichi* as described by Hofker (1948) we have to do with fossil forms. This species is only known in numerous samples from the lower part of the upper Oligocene and the upper part of the middle Oligocene of the Netherlands and northwestern Germany, whereas one of the other so-called generations, *A. staeschei*, is known exclusively from the middle Miocene of the same region and only the other, *A. frankei*, is known to occur in both Miocene and Oligocene. Hofker did not mention in what stratigraphic zones of the Tertiary drillings at Maris and Beeringen his material was collected, nor did he indicate the exact depth of his samples. He did not even mention if he found his generations associated in the same beds. However, in the numerous samples from the Maris and Beeringen drillings and from many other localities examined by ten Dam and Reinhold, where the stratigraphic positions of the samples was fixed by numerous macrofossils, the different stratigraphic distribution of the three abundantly represented species is quite evident. In view of the fact that it is extremely difficult to prove the existence of trimorphism in recent Foraminifera and that it is certain many Foraminifera do not show trimorphism at all, it seems rather farfetched to assume that these three forms, although certainly closely related, should be the three generations of a single species and that for some unknown reason two of these generations should be restricted to different stratigraphic zones, which may have an absolute age-difference of many hundred thousand years.

It seems to me that the only reasonable conclusion is that there really exist three different, but closely related species of *Asterigerina* in the Dutch Miocene and Oligocene, two of which are restricted to definite and different stratigraphic zones.

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OCCURRENCE OF *TEMPSKYA* IN THE LOWER CRETACEOUS OF THE WESTERN INTERIOR

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In the course of field work near Castle Dale, Emery County, Utah, several well-preserved pieces of a trunk of the fern *Tempskya* were found in beds which also yield the characteristic Lower Cretaceous fresh-water pelecypod *Eupera onestae* (Katich, 1951). *Tempskya* has not, so far as is known, been found in beds older than late Cretaceous in Utah, but a specimen purporting to come from the Morrison formation (Jurassic) near Greybull, Wyoming, has recently been reported (R. W. Brown, personal communication). A specimen of *Tempskya* was collected by W. L. Stokes from the Dakota sandstone near Thompsons, Utah, which is identical to the Castle Dale species. Stokes' specimen was identified by Brown (1950, p. 49) as *T. knowltoni* Seward. Re-examination of the specimen collected by Stokes and comparison of it with the ones collected by the writer has led Brown to suspect that the Utah forms are not *T. knowltoni* but probably a new species.

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NOMENCLATURAL NOTES

TAXONOMIC COMMENT ON: CHECKLIST OF SALINITY TOLERANCE OF POST-PALEOZOIC FOSSIL OSTRACODA BY I. G. SOHN

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A recent article by I. G. Sohn (1951) has come to my attention. In this article Sohn gives a table which he states "records the inferred salinity tolerance of 80 forms included in 36 genera." The report is accompanied by a bibliography of 24 papers, and his table indicates the source of his information. Unfortunately, some of the papers were published nearly 100 years ago when few genera of post-Paleozoic Ostracoda were recognized and Sohn has made little attempt to place them in the genera now in current use. Many of the genera mentioned were originally described from living species whose habitat is definitely known. Several of the species mentioned have become the genotypes of other genera. The concept of Sohn's paper is excellent, and the report is likely to be referred to by students of sedimentation who are not familiar with post-Paleozoic ostracodes as a check on the ecology of sediments in which ostracodes occur. I therefore feel that I should point out a few of the obvious corrections which should be made in the checklist before it results in serious misconceptions.

1. "*Amonocythere*" (p. 64) obviously was intended for the genus *Anomocytheridea* Stephenson (1938, p. 141, pl. 23, fig. 15; pl. 24, figs. 7, 8; text figs. 2, 6, 19, 20).
2. "*Bythocythere simplex*" (p. 64). This species described by Norman (1867, p. 17, pl. 5, figs. 1–4) under the name *Cythere simplex*, was chosen by Sars (1926, p. 241) as genotype of *Macrocythere*, and has been so reported in many papers since that date. Actually, the same species was selected as genotype of *Jonesia* by Brady (1866, p. 363, pl. 57, figs. 11 a–c). It should read therefore *Jonesia simplex* (Norman).
3. "*Cyprideis*" (p. 64) and "*Cytheridea torosa*" and var. "*litoralis*" [sic.] (p. 65). *Candona torosa* Jones (1850, p. 27, pl. 3, fig. 6) was the species used by Jones (1857, p. 21, pl. 2, figs. 1a–i) as subgenotype of *Cyprideis*, which he then suspected belonged under *Cythere*. Later workers have, however, accepted it as a valid genus. The variety was originally named *Cytheridea littoralis* by Brady (1869, p. 125). Brady indicated that its habitat is exclusively brackish water. Elofson (1941, pp. 256–258), whose large report is devoted primarily to ostracode ecology, has discussed this variety in detail under the name *Cyprideis litoralis* [sic.] (Brady).
4. "*Cythere*" (p. 64). The genotype of *Cythere* is *C. lutea* O. F. Müller, and the discussion of its carapace by Blake (1931, pp. 160–161) points out that the genus has been much misunderstood and that: "At present *Cythere* appears to be a very small genus comprising, probably, fewer than ten species, recent and fossil." It is doubtful if any of the species listed by Sohn actually belong under this genus.
5. "*Cythere cornuta*" (p. 64) (Roemer) was mentioned by Moreman (1927), p. 98), but not figured. This was described by Alexander (1929, p. 85) as *Cythere cornuta gulfensis*, but later Alexander (1933, p. 207) referred it to *Brachycythere alata* (Bosquet), at the same time placing *Cytheropteron saratogana* Israelsky (1929, p. 10, pl. 2A, figs. 4 a–c) in its synonymy. Murray and Hussey (1942, p. 172), after examining specimens from Bosquet's European locality denied this identity. It would appear then that this species should be referred to as *Alatacythere saratogana* (Israelsky).
6. "*Cythere crispata*" (p. 64). *C. crispata* Brady (1868*c*, p. 221, pl. 14, figs. 14, 15) is a living marine species described from Tenedos. It was referred to *Leptocythere* by Sars (1925, p. 175) when he described that genus.
7. "*Cythere limicola*" (p. 64). This living species was originally described by Norman (1867, p. 20, pl. 6, figs. 1–4) as *Cythereis limicola* from Dogger Bank, 100 miles east of Tynmouth. Sars (1925, p. 181) selected it for the genotype of *Kyphocythere*, not knowing apparently that Hirschmann (1916, p. 582) had previously used it as the genotype of *Palmanella*. Its name should be *Palmanella limicola* (Norman).
8. "*Cythere retirugata*" (p. 64) and "*Macrodentina*" (p. 65). *Cythere retirugata* Jones (1885, p. 350, pl. 9, figs. 21–23), was one of the two species on which Martin (1940, p. 325–330) based his description of the genus *Macrodentina*. The name should be *Macrodentina retirugata* (Jones).
9. "*Cythere tuberculata*" (p. 64). By my records, the first use of this name was *Cythere* (*Cytherideis*) *tuberculata* Jones (1857, p. 47) for one of the nine species on which Jones erected *Cytherideis* as a subgenus of *Cythere*. Jones and Sherborn (1889, p. 11) transferred this

species to *Potamocypris*. *Cythere tuberculata* (Sars) of Brady and others was originally described as *Cythereis tuberculata* Sars (1865, p. 37). It is apparently a *Trachyleberis*. *Cythere tuberculata* Terquem (1878, p. 119, pl. 14, figs. 3a–c), from the Pliocene of Rhodes, is a junior homonym.

10. "*Cytherideis unicornis*" (p. 65), described by Jones (1856, p. 158, pl. 7, figs. 24–26) as *Cythere* (*Cytherideis*) *unicornis*, was by Jones and Sherborn (1889, p. 14) referred to the synonymy of *Cypridea spinigera* (Sowerby).
11. "*Cytherideis unisulcata*" (p. 65), described by Jones (1856, p. 157, pl. 7, fig. 23) as *Cythere* (*Cytherideis*) *unisulcata*, was by Jones (1893, p. 387) referred to the genus *Potamocypris*.
12. "*Cytheropteron virgineum*" (p. 65). This refers to the specimen figured by Stadnichenko (1927, p. 241, pl. 39, figs. 4–7), which is not a *Cytheropteron*. Murray and Hussey (1942, p. 177, pl. 28, figs. 6, 10; text figs. 2, 4, 8, 9, 10) described *Brachycythere martini*, and on page 178, indicated that Stadnichenko's specimen belonged with their species.
13. "*Herpetocypris aequalis*" (p. 65) doubtless refers to *Erpetocypris aequalis* Chapman (1935, p. 67, pl. 2, figs. 1a, b). The genus *Erpetocypris* was described by Brady and Norman in 1889 (p. 84), and while the same authors in a later part of their monograph (1896, p. 722) changed the spelling to *Herpetocypris*, Chapman followed the rules in his description of this species. For an excellent discussion of the principles involved, the reader may consult Moore, Weller, and Knight (1942).
14. "*Limnicythere zindorfi*" (p. 65). This involves much the same question as the preceding species listed. Brady (1868*a*, p. 121) described the genus *Limnocythere* in the *Intellectual Observer*. Later in the same year Brady (1868*b*, p. 419) changed the spelling without giving reasons. Both spellings have been used by later authors, but *Limnocythere* definitely has priority.
15. "*Loxoconcha elliptica*" (p. 65). This living species was described by Brady (1868b, p. 435, pl. 27, figs. 38, 39, 45–58; pl. 40, fig. 3) from brackish water pools in Guernsey. *Loxoconcha elliptica* Bonnema (1941, p. 26, pl. 6, figs. 6–11) from the Cretaceous of Holland is a junior homonym of Brady's species, and I, therefore, suggest that in the future it be referred to as *Loxoconcha bonnemai* Howe, new name.
16. "*Schlerochylus*" (p. 65) obviously was intended for *Sclerochilus* Sars (1865, p. 89), the genotype of which was the living species *Cythere contorta* Norman (1862, p. 150, pl. 3, fig. 15). It was found in shell sand at Berwick-on-Tweed and is marine.
17. *Thaumatocypris* (p. 65). The two Jurassic species listed might easily give an erroneous impression as the natural habitat of this genus. *T. echinata* Müller (1906, p. 42, pl. 6, figs. 1–5, 10) is a living species described from 0° 58′ S, 99° 43′ E, in the Indian Ocean, near the equator, from a depth of 1100 metres.

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NEOSPHAEROCONCHIDIUM, A NEW NAME FOR *CONCHIDIUM* HAECKEL, PREOCCUPIED

ARTHUR S. CAMPBELL
University of California, Berkeley

Dr. R. C. Moore has kindly informed me that the phaeodarian (Radiolaria) genus *Conchidium* Haeckel, 1879 (Sitzungsb. mednat. Gesellsch. Jena, Dec. 12, p. 6), is preoccupied. According to Neave, 1939, (Nomenclator Zoologicus) this name was given by Linneaus, 1768, to a pentameracean brachiopod (*C. biloculare* L.) from the Silurian of Gotland. The name is also cited in Wallenberg, 1819 (N. Acta Soc. Upsal., 8, 63), for the same brachiopod. I, therefore, propose *Neosphaeroconchidium* (recent round sea shell) as a substitute. The type species is *Conchidium terebratula* Haeckel (1887, p. 1721, pl. 124, figs., 1, 2). Haeckel introduced seven other species in this important genus.

A NEW NAME FOR A PLEISTOCENE FORAMINIFER FROM THE NETHERLANDS

J. H. VAN VOORTHUYSEN
Haarlem, Netherlands

Professor Hans E. Thalmann kindly informed us that *Nonion barleeanum* (Williamson) var. *inflatum* van Voorthuysen from the Pleistocene of the Netherlands was preoccupied by *Nonionina inflata* Alth., described in 1850 (Haidinger's Naturw. Abh., vol. 3, (2), 266, pl. 13, fig. 22).

Therefore, the following new name for this

new variety is proposed in spite of the fact that we reassigned it in a later publication to *Anomalinoides* (The quantitative distribution of the Pleistocene, Pliocene and Miocene Foraminifera of boring, Zaandam, Netherlands: Med. Geol. Stichting, N. S., no. 4, 1950, p. 66, pl. 4, fig. 3a, b).

Anomalinoides barleeanum (Williamson) var. *zaandamae* van Voorthuysen

This new name is proposed for the above mentioned homonym published in: The quantitative distribution of the Plio-Pleistocene Foraminifera of a boring at the Hague (Netherlands): Med. Geol. Stichting, N.S., no. 4, 1950, p. 41, pl. 3, fig. 6a, b.

JOURNAL OF PALEONTOLOGY, VOL. 26, NO. 4, PP. 682–692, 5 TEXT FIGS., JULY 1952

SOCIETY RECORDS AND ACTIVITIES

REPORTS AND MINUTES OF THE TWENTY-SIXTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

The twenty-sixth annual meeting of the Society of Economic Paleontologists and Mineralogists was held at the Biltmore Hotel in Los Angeles, California, March 24–27, 1952, in conjunction with the annual meeting of The American Association of Petroleum Geologists.

A field trip to Palos Verdes Hills, across the Los Angeles Basin, and through the Rosecrans, Torrance, and Inglewood fields, was arranged for Monday afternoon, March 24.

The Presidential Address of the Society, "Paleofacies, the geologist's new tool," was given by Thomas H. Philpott in the joint session on Tuesday, March 25, and W. H. Twenhofel was honored with an award in recognition of his service to the Society. Also in the joint session, "Shallow water sediments of the northern Gulf of Mexico" was read by Francis P. Shepard.

A dinner honoring charter members of the Society was given in the Music Room of the Biltmore Hotel at 7:00 P.M., Tuesday.

The first part of the technical program of the Society, with Morton B. Stephenson and James L. Cowell presiding, began at 9:00 A.M., Wednesday, March 26, and continued until 12:00 noon. The following papers were presented.

Daniel J. Jones, "Ostracoda from Pleistocene lacustrine sediments, Great Salt Lake Valley, Utah."

Orville L. Bandy, "The frequency distribution of Recent Foraminifera off California"

Zach M. Arnold, "Paleontology and the study of variation in living Foraminifera"

Manley Natland, "Pleistocene and Pliocene stratigraphy of Southern California"

Joseph J. Graham, "Miogypsina in California"

Clifford C. Church, "Foraminifera from the Franciscan Calera limestone"

Hans E. Thalmann, "Twenty years of 'Foraminiferal Statistics' "

Hans E. Thalmann, "Review of recent Foraminiferal studies by Russian authors"

John Chronic and Halka Chronic, "Composition and implications of Pennsylvanian faunule from Colorado"

W. T. Rothwell, "Fossil fish scales in exploration for petroleum"

R. A. Stirton, "Vertebrate paleontology and continental stratigraphy in Colombia"

A symposium on Research Objectives in Modern Sedimentology and Paleontology, with Harold W. Scott and W. T. Rothwell presiding, was presented from 2:00 to 5:00 P.M., Wednesday, March 26. The following papers were given.

Roger Revelle, "What are the oceanographers up to"

Benjamin H. Burma, "Trends of research in paleontology"

Fred B. Phleger, "Significance of new research on Foraminifera"

W. C. Krumbein, "Research objectives in sedimentology"

Ben Cox, "Research in modern geology and its application to petroleum exploration"

The third part of the technical program, with Robert S. Dietz and Clifford C. Church presiding, was presented from 9:00 A.M. to 12:00 noon, Thursday, March 27. The following papers were read.

Douglas L. Inman, "Seasonal variations in texture of beach and near-shore sediments at La Jolla, California"

K. O. Emery, "Some Southern California shelf sediments"

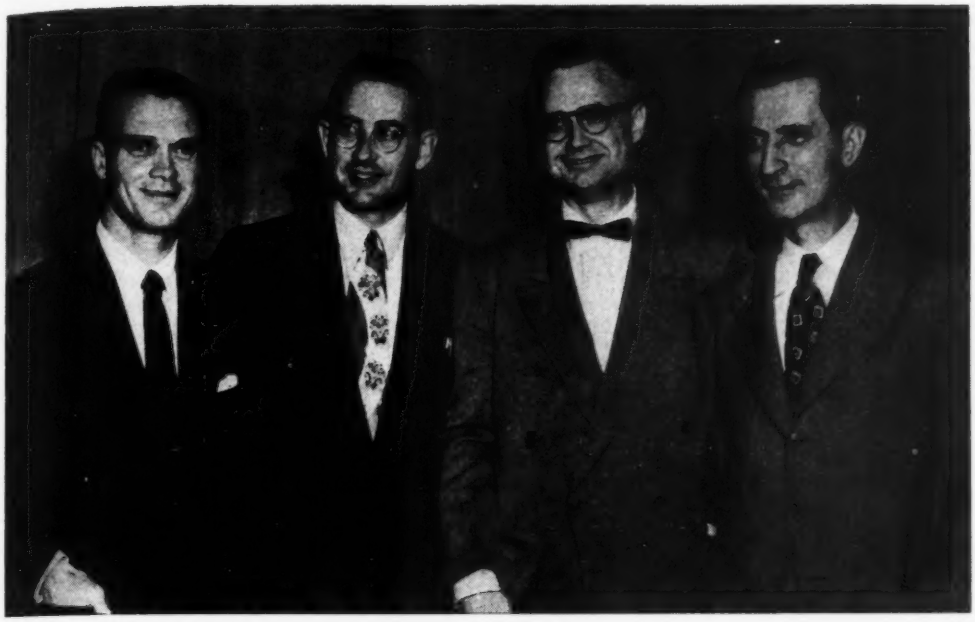
S. C. Rittenberg and K. O. Emery, "Transformations of organic matter in Recent basin sediments"

Roland F. Beers and Shepard W. Lowman, "The sedimentology and geochemistry of the Black Sea"

J. E. Holzman, "Submarine geology of Tanner and Cortes banks"

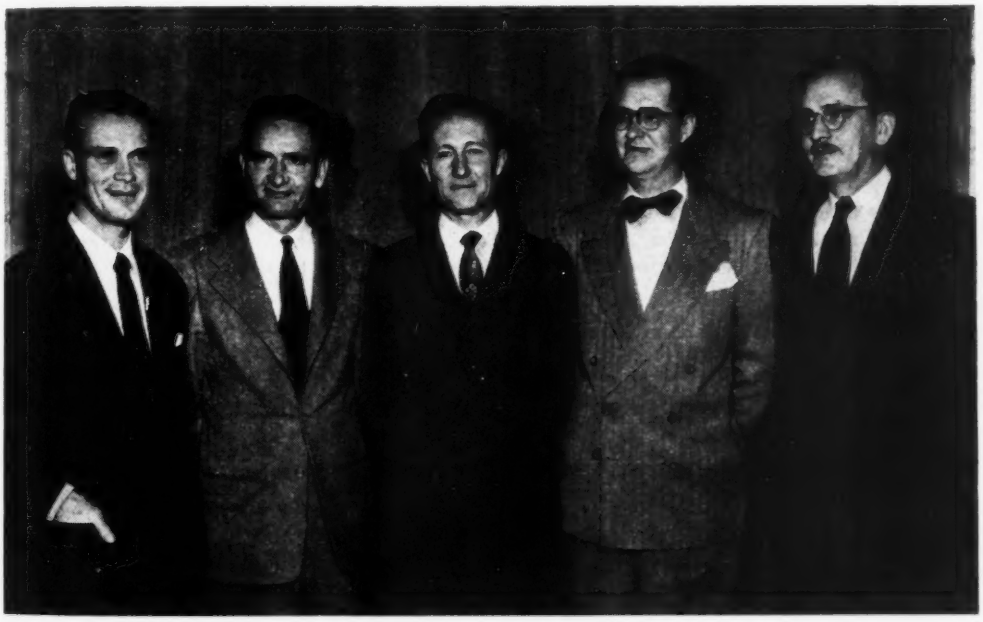
Edwin L. Hamilton, "Sediments from some flat-topped seamounts of the mid-Pacific"

The following papers were presented in a general session from 2:00 to 4:00 P.M.,



OUTGOING OFFICERS

Left to right: C. G. Lalicker, *Sec.-Treas.;* K. O. Emery, *Vice Pres.;* T. H. Philpott, *Pres.;* W. C. Krumbein, *First past Pres.*



NEW OFFICERS—1952–53

Left to Right: C. G. Lalicker, *Sec.-Treas.;* M. B. Stephenson, *Vice Pres.;* C. C. Church, *Pres.;* G. E. Murray, *Co-Editor—Paleontology:* Jack L. Hough, *Editor—Mineralogy.* (Absent from Photo—L. J. Wilbert, Jr., *Co-Editor—Paleontology.*)

Thursday, March 27, with W. C. Krumbein and Cecil G. Lalicker presiding:

Sherman A. Wengerd, "Graphic techniques in section measurement";

Dan E. Feray, "Edwards core study, Texas";

Raymond Sidwell and G. Frederick Warn, "Sedimentation and petrology of Pennsylvanian deposits in Upper Pecos Valley, New Mexico";

W. D. Keller, "Analcime in the Popo Agie member of the Chugwater formation";

G. Frederick Warn, R. P. Carmack, Raymond Sidwell, "The Spraberry sands of the Midland Basin, Texas";

John F. Mann, Jr., "Some sedimentary features of the Temecula arkose";

Thomas Clements, "Calcareous dunes of Death Valley, California."

The meeting adjourned at 4:00 P.M.

The annual business session of the Society was called to order at 4:00 P.M., Thursday, March 27, by Thomas H. Philpott, president.

The minutes of the 1951 meeting were approved as published in the *Journal of Paleontology*, vol. 25, no. 4 (July, 1951).

The following reports were given.

1. *Report of the Editors of the Journal of Paleontology (J. Marvin Weller, outgoing; Grover E. Murray and Louis J. Wilbert, Jr., incoming).*—Volume 25 of the Journal of Paleontology, issued in conjunction with the Paleontological Society in 1951, contains 829 pages and 118 collotype plates. Published in it are 50 paleontological papers, one article on biometry, three describing techniques and instruments, 17 paleontological notes, 14 nomenclatural notes, 1 bibliographic note, 7 reviews, data relating to membership and activities of the two societies and other miscellaneous material.

The March, July, and November numbers were prepared by your editor on behalf of the Society of Economic Paleontologists and Mineralogists. These numbers consist of 378 pages and 45 collotype plates, a decrease of 24 pages and an increase of 6 plates, as compared with the previous volume. The contributions in these numbers may be classified as follows.

	Paleozoic	*Mesozoic*	*Cenozoic*
Paleobotany	1	1	1
Foraminifera	1	3	4
Corals	1		
Crinoids	1		
Cephalopods	1	1	
Trilobites	2		
Crustacea	2	2	2
Conodonts	1		
Vertebrates	1	1	

Six of these papers are concerned with fossils from foreign countries. In addition are: an article on biometry, the description of an instrument, two papers on technique, 8 paleontological notes, 6 nomenclatural notes, a bibliographic note, and 5 reviews.

After seeing the November number through the press, all unpublished manuscripts, current correspondence, and other materials were turned over to the new editors.

A sufficient number of manuscripts are on hand to make up issues through 1952. They continue to arrive at a rate in excess of that at which they can be published in a 128-page issue. The new editors have increased current issues to 160 pages and will attempt to follow this policy as long as finances permit.

Authors are being encouraged to emphasize the stratigraphic and ecologic aspects of their work whenever possible.

2. *Report of the Editor of the Journal of Sedimentary Petrology (Jack L. Hough).*—The Journal of Sedimentary Petrology was published in 1951 as volume 21, numbers 1 through 4. Each number contained approximately 64 pages. The contents of the volume include 28 articles, 8 reviews, 4 announcements, 3 discussions, an index, and 9 pages of advertisements.

The distribution of papers according to national origin was as follows: United States, 16; Netherlands, 3; Australia, 3; England, 2; New Zealand, 1; British West Indies, 1; Denmark, 1; and Egypt, 1.

The size of the *Journal* has continued to be in good adjustment to number of papers accepted for publication. There has been, on the average, an eight-months period between date of receipt of a paper and the time of its publication.

Financially, the *Journal* has paid for itself and made a small profit during the year. This was possible, in part, because of assistance rendered by the University of Illinois in providing a half-time editorial as-

sistant and in part by a small advertising income. It is believed that more advertising accounts could be obtained but the editor has not had time to develop this possibility. During the coming year advertising will be handled by Thomas H. Philpott, past-president.

A symposium on *Turbidity Currents and the Transportation of Coarse Sediments to Deep Water* was published in November, 1951, as Special Publication No. 2 of the Society of Economic Paleontologists and Mineralogists. This was edited by the editor of the *Journal of Sedimentary Petrology*. The cost of publication was recovered by pre-publication sales and by January 1, 1952, a profit of approximately $400 had been made.

3. *Report of the Secretary-Treasurer* (*Cecil G. Lalicker*).—

BACK VOLUME SALES
(March 1, 1951 to March 1, 1952)

Back volumes of the Journal of Paleontology	$2,995.08
Back volumes of the Journal of Sedimentary Petrology	881.79

SPECIAL PUBLICATION SALES
(March 1, 1951 to March 1, 1952)

Turbidity Currents	$2,791.44

PRINTING AND ENGRAVING BILLS FOR 1951

Journal of Paleontology

	Banta Printing Bills	*Meriden Engraving Bills*	*Total Printing and Engraving Bills*	*S.E.P.M. Total Printing and Engraving Bills*
Number 1 (January)*	$ 1,633.17	$ 768.15	$ 2,401.32	
Number 2 (March)	1,732.13	496.98	2,229.11	$2,229.11
Number 3 (May)*	2,174.17	713.16	2,887.33	
Number 4 (July)	1,872.54	493.81	2,366.35	2,366.35
Number 5 (Sept.)*	2,380.60	934.31	3,314.91	
Number 6 (Nov.)	1,964.15	567.80	2,531.95	2,531.95
	$11,756.76	$3,974.21	$15,730.97	$7,127.41
(1950 Totals)	($10,430.55)	($2,942.88)	($13,373.43)	($6,766.11)

* Odd numbers paid by Paleontological Society.

Journal of Sedimentary Petrology

Number 1 (March)	$ 869.23
Number 2 (June)	937.05
Number 3 (Sept.)	980.12
Number 4 (Dec.)	892.10
	$3,678.50
(1950 Total)	($3,543.50)

Turbidity Currents and the Transportation of Coarse Sediments to Deep Water

Banta Printing Bills	$1,720.50
Miscellaneous Expense	508.55
Total	$2,229.05

MEMBERSHIP, MAILING, AND JOURNAL STATISTICS

	March 1952	*March 1951*	*March 1950*
1. S.E.P.M. Membership:			
Active Members	583	563	478
Associate Members	288	229	193
Honorary Members	1	1	1
Correspondents	5	5	5
TOTAL	877	798	677
2. Journal of Paleontology Mailing List:			
S.E.P.M. Active Members	373	362	319
S.E.P.M. Associate Members	167	130	110
Subscribers	538	519	505
P.S. Members	511	443	390
TOTAL	1,589	1,454	1,324
3. Journal of Sedimentary Petrology Mailing List:			
S.E.P.M. Active Members	331	337	279
S.E.P.M. Associate Members	170	133	98
S.E.P.M. Correspondents	5	5	5
Subscribers	489	449	413
TOTAL	995	924	795
4. Number of pages in 1951 Journal of Paleontology	829 (762, 1950)		
5. Number of plates in 1951 Journal of Paleontology	118 (90, 1950)		
6. Total edition of 1951 Journal of Paleontology	1,800 (1,700, 1950)		
7. Number of pages in 1951 Journal of Sedimentary Petrology	241 (231, 1950)		
8. Total edition of 1951 Journal of Sedimentary Petrology	1,200 (1,200, 1950)		
New Members from March 1, 1951, to March 1, 1952	40 (69, 1950–1951)		
New Associates from March 1, 1951, to March 1, 1952	78 (90, 1950–1951)		
Transfers to Active Membership, March 1, 1951, to March 1, 1952	1 (36, 1950–1951)		

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
CERTIFICATE OF CERTIFIED PUBLIC ACCOUNTANTS

To the Council, Society of Economic Paleontologists and Mineralogists:

We have examined the balance sheet of Society of Economic Paleontologists and Mineralogists at December 31, 1951, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of Society of Economic Paleontologists and Mineralogists at December 31, 1951 and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

ARTHUR YOUNG & COMPANY

January 30, 1952

BALANCE SHEET AT DECEMBER 31, 1951

ASSETS	*Total*	*General Fund*	*Publication Fund*
CURRENT ASSETS:			
Cash	$ 8,191.56	$ 8,177.56	$ 14.00
Savings account	2,408.93	2,408.93	—
Accounts receivable (less reserve, $82.90)	1,088.78	708.29	380.49
Total current assets	$11,689.27	$11,294.78	$ 394.49
PUBLICATIONS:			
Journal of Paleontology:			
Issues prior to 1951—18,058 at $.50 each (2,957 complete volumes)	$ 9,029.00	$ 9,029.00	$ —
Issues 1 to 6 of 1951—793 journals, at cost	1,204.87	1,204.87	—
Reprints in 1948, Vol. 1, 1927—822 vols., at cost	1,810.95	1,810.95	—
Journal of Sedimentary Petrology:			
Issues prior to 1951—2,792 journals at $.50 each (866 complete volumes)	1,396.00	1,396.00	—
Issues 1 to 4 of 1951—550 journals, at cost	448.34	448.34	—
Special publication:			
Turbidity Currents, 953 issues, at cost	814.91	—	814.91
Total publications	$14,704.07	$13,889.16	$ 814.91
FURNITURE AND FIXTURES (less reserve, $840.12)	$ 1.00	$ 1.00	$ —
DEFERRED CHARGES	$ 781.72	$ 781.72	$ —
	$27,176.06	$25,966.66	$ 1209.40
LIABILITIES AND SURPLUS			
CURRENT LIABILITIES:			
Accounts payable	$ 123.55	$ 123.55	$ —
Amount payable to Paleontological Society	2,387.83	2,387.83	—
Accrued printer's charges	950.00	950.00	—
Total current liabilities	$ 3,461.38	$ 3,461.38	$ —
DEFERRED CREDITS			
Subscriptions to journals (less $1,226.42 payable to Paleontological Society)	$ 3,508.89	$ 3,508.89	$ —
Membership dues for 1952 and 1953	3,383.90	3,383.90	
Advance collection for 1952 engraving	150.00	150.00	—
Total deferred credits	$ 7,042.79	$ 7,042.79	$ —
SURPLUS (per accompanying statement)	$16,671.89	$15,462.49	$1,209.40
	$27,176.06	$25,966.66	$1,209.40

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
STATEMENT OF INCOME AND SURPLUS
FOR THE YEAR ENDED DECEMBER 31, 1951

	Total	*General Fund*	*Publication Fund*
INCOME:			
Membership dues and subscriptions:			
Journals of Paleontology and Sedimentary Petrology	$ 2,220.00	$ 2,220.00	$ —
Journal of Paleontology	7,847.85	7,847.85	—
Journal of Sedimentary Petrology	3,874.47	3,874.47	—
	$13,942.32	$13,942.32	$ —
Sales of special publication—Turbidity Currents	$ 2,623.54	$ —	$2,623.54
Sales of back numbers:			
Journal of Paleontology, Volume 1, 1927	$ 176.55	$ 176.55	$ —
Journal of Paleontology, Volumes 2 to 25	2,874.93	2,874.93	—
Journal of Sedimentary Petrology	559.49	559.49	—
	$ 3,610.97	$ 3,610.97	$ —
Sales of plates	$ 278.53	$ 278.53	$ —
Advertising	$ 200.00	$ 200.00	$ —
Miscellaneous	$ 286.64	$ 286.64	$ —
	$20,942.00	$18,318.46	$2,623.54
Less: Proportion of 1951 income accrued to Paleontological Society	2,395.19	2,395.19	—
	$18,546.81	$15,923.27	$2,623.54
COSTS AND EXPENSES:			
Cost of printing:			
Journal of Paleontology	$ 7,388.65	$ 7,388.65	$ —
Journal of Sedimentary Petrology	3,987.87	3,987.87	—
Special publication—Turbidity Currents	1,720.50	—	1,720.50
	$13,097.02	$11,376.52	$1,720.50
Expenses:			
Clerical salaries	$ 2,376.25	$ 2,376.25	$ —
Employees pension and death benefits plan expense	501.33	501.33	—
Office supplies and expense	1,215.97	783.59	432.38
Postage and express	830.11	753.94	76.17
Office rent	768.00	768.00	—
Insurance and bond	46.79	46.79	—
Audit fee	100.00	100.00	—
Taxes	55.19	55.19	—
Miscellaneous	309.90	309.90	—
	$ 6,203.54	$ 5,694.99	$ 508.55
Adjustment for (increase) decrease in inventory of publications	$ (128.56)	$ 686.35	$ (814.91)
	$19,172.00	$17,757.86	$1,414.14
NET INCOME (LOSS)	$ (625.19)	$(1,834.59)	$1,209.40
SURPLUS AT DECEMBER 31, 1950	$17,297.08	17,297.08	—
SURPLUS AT DECEMBER 31, 1951	$16,671.89	$15,462.49	$1,209.40

4. *Report of the Research Committee (Harold W. Scott, chairman).*—The Research Committee, composed of S. W. Lowman, R. V. Hollingsworth, E. C. Dapples, R. W. Rolshausen, H. W. Menard (vice-chairman), and H. W. Scott (chairman), felt that it was time for an analysis of "objectives" in geological research. It was decided at the 1951 meeting of the committee that a symposium should be held on this subject at the Los Angeles meeting in 1952. The symposium was presented under the title of "Research Objectives in Modern Sedimentology and Paleontology."

The committee considered the matter of awards in paleontology and sedimentology.

It was moved by Grover Murray, seconded by H. W. Menard, and unanimously approved by all committee members present, that the Research Committee be responsible for working out and implementing a plan to select the best paper published in the *Journal of Paleontology* and the best paper in the *Journal of Sedimentary Petrology*. Determination should be made by the subscriber-members, one vote per member per subscription. This award is to be made from papers published during the second prior calendar year.

During discussion of the above motion it was proposed that a ballot be published in the *Journals*. This ballot would be for the use of the membership in expressing its opinion on published research.

It was moved by H. W. Menard, seconded, and unanimously approved, that the Research Committee recommend that the Council award a commendation for outstanding service to the Society to one or more candidates chosen by the Research Committee.

In discussion it was brought out that the committee would not necessarily present one candidate every year; it might be that none would be recommended. This would be left to the discretion of the committee.

These ideas were presented to the Council. The Council then encouraged the Research Committee to continue their plans for setting up such awards.

5. *Presidential Summary (Thomas H. Philpott).*—President Philpott reviewed the Society's progress during the past several years, calling particular attention to the increase in membership and the distribution of the *Journal of Paleontology* and the *Journal of Sedimentary Petrology*. Mr. Philpott also announced that pre-publication sales of the Society's new symposium, *Turbidity Currents and the Transportation of Coarse Sediments to Deep Water*, were so great that it was necessary to complete the loan from The American Association of Petroleum Geologists. The following graphs were shown for emphasis. (See pp. 690–691.)

6. *Report of the Pacific Section.*—At the annual meeting, the Pacific Section elected as president, W. Thomas Rothwell of the Richfield Oil Corporation at Long Beach; and as secretary-treasurer, James L. Cowell of the Shell Oil Company at Ventura.

On December 8 and 9, 1951, a week-end field trip was arranged to visit the Paleozoic Section in Death Valley. The leader of this trip was James McAllister of the United States Geological Survey.

On January 14, 1952, the geological department of the University of Southern California was host to the Section. Three very interesting papers were presented, as follows:

"The Capistrano formation," by W. R. White, paleontologist with The Texas Company;

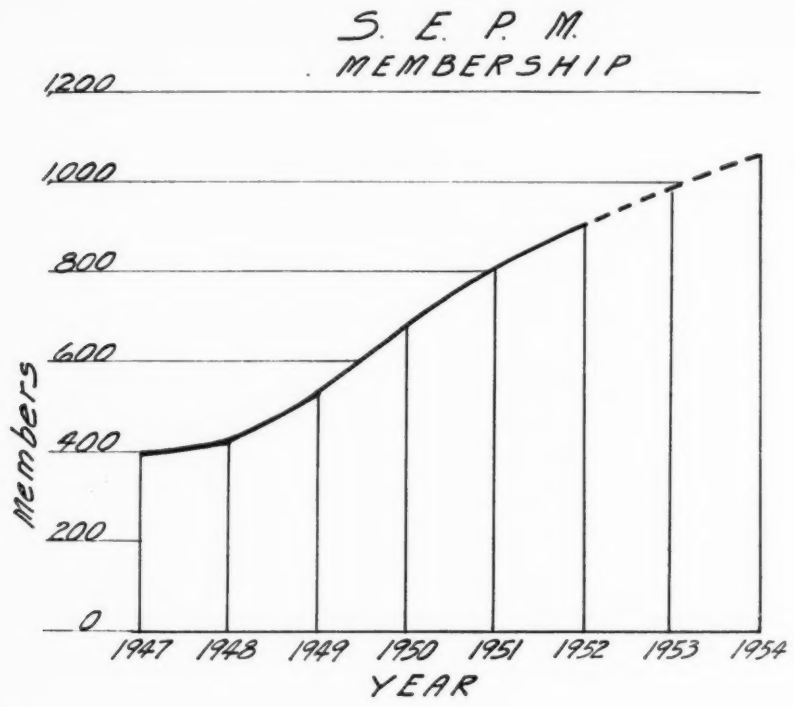
"Playa sediments," by Dick Stone, graduate student at the University of Southern California;

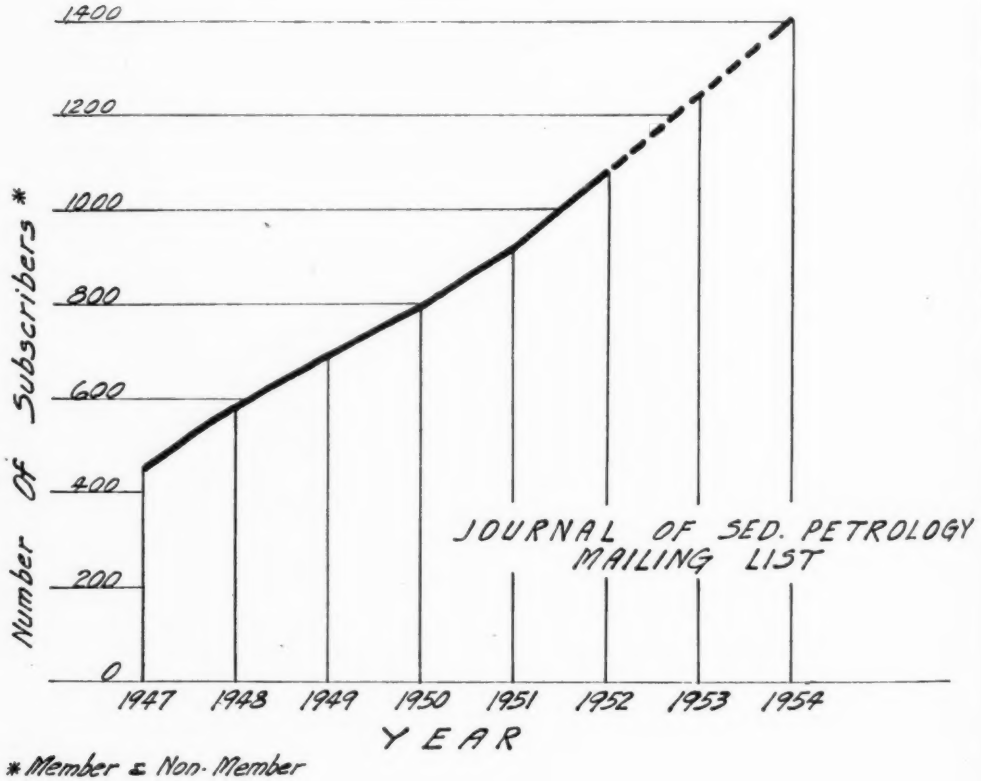
"The submarine geology of Cortez and Tanner banks," by J. E. Holzman, geologist with the Shell Oil Company.

On February 16, more than 200 geologists and paleontologists turned out for a field trip in the Castaic area. Numerous stratigraphic and structural problems on the San Gabriel Fault and environs were intensively discussed on the spot. W. H. Corey, of the Continental Oil Company; John Crowell, of the geology department of the University of California at Los Angeles; and R. H. Jahns of the geology department at the California Institute of Technology were leaders of discussions at several stops on the trip.

During March and April, no local meetings were scheduled other than participation in the National Convention.

May 10 is the date of a field trip to the





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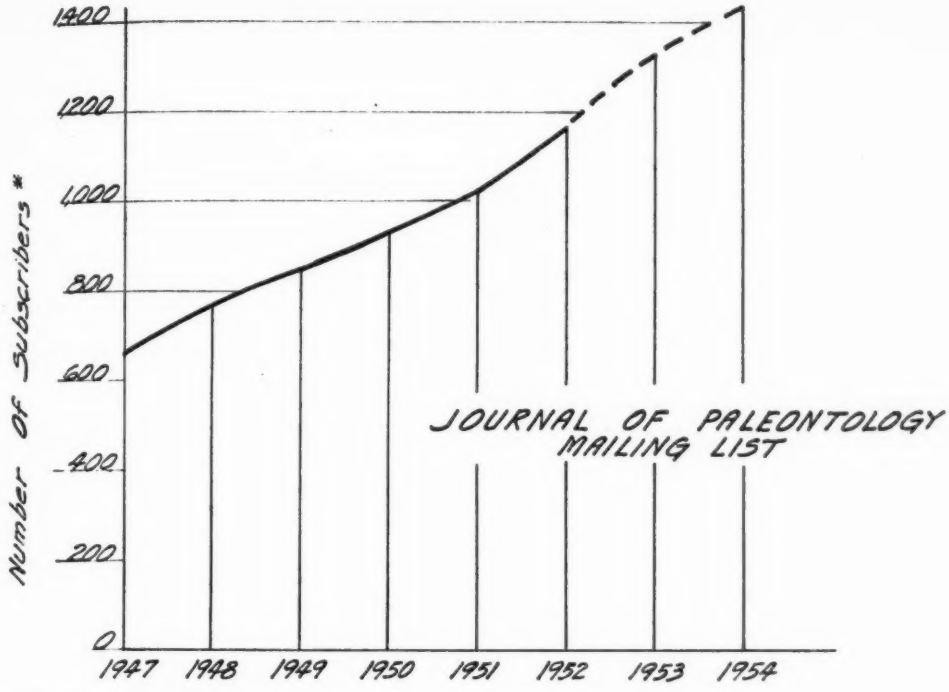

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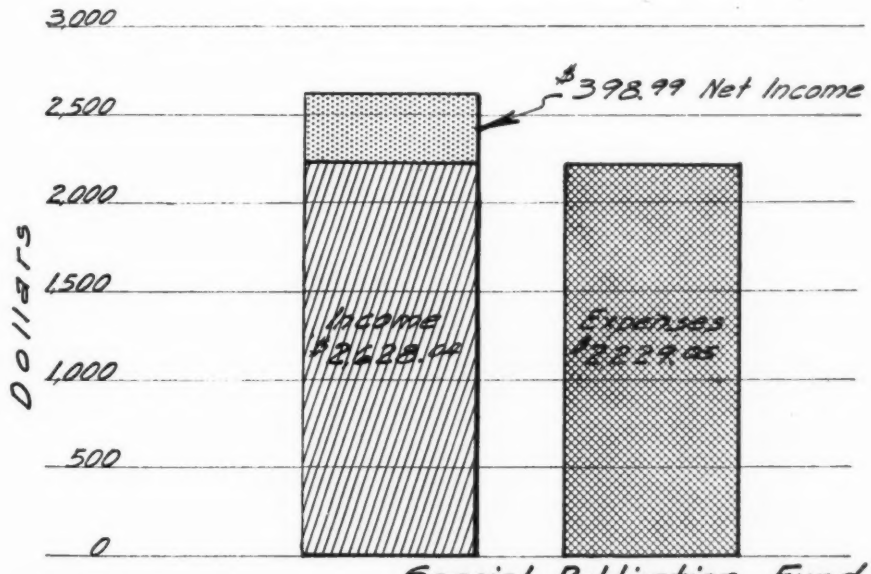

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type sections of the Vaqueros formation and the Relizian Stage.

It was moved by W. C. Krumbein, seconded, and approved that all of the foregoing reports be accepted.

It was moved by Jack Hough, seconded, and approved, that the following resolutions be adopted.

BE IT RESOLVED THAT in behalf of the Society we extend an expression of our sincere thanks to the following:

TO H. W. Scott, chairman of the Research Committee, and the members of his committee, for the excellent research symposium for the 1952 annual meeting in Los Angeles;

TO Hollis D. Hedberg and his Committee on Members and Papers for their very excellent continued service in obtaining material for publication in the *Journals* and for securing new members for the Society;

TO K. O. Emery, chairman, and the members of the S.E.P.M. Technical Program for the high quality of the papers secured for the 1952 program;

TO Louis J. Simon and his Housing Committee for finding satisfactory accommodations for our members;

TO the Pacific Sections of the A.A.P.G. and S.E.P.M. and the Californians of the S.E.G., and especially to W. Thomas Rothwell (Pacific Section President), to Orville L. Bandy, Herschel L. Driver, and Aden Hughes, chairmen of the various convention committees, for their praiseworthy management of the 1952 annual meeting;

AND TO the Biltmore Hotel for the very satisfactory manner in which it has provided facilities for the 1952 meeting.

The results of the election of officers by mailed ballot, for the new year, were announced by outgoing-president Thomas H. Philpott as follows: President, Clifford C. Church; Vice-President, Morton B. Stephenson; Secretary-Treasurer, Cecil G. Lalicker.

The business session adjourned at 5:00 P.M., Thursday, March 27, 1952.

JOURNAL OF PALEONTOLOGY, VOL. 26, NO. 4, PP- 693–695, JULY 1952

NOTICES

SEARCHING FOR RADIOACTIVE MINERALS IN ROUTINE EXPLORATION FOR OIL AND GAS

On June 5, at Denver, Colorado, delegates appointed by the presidents of A.A.P.G., S.E.G., and S.E.P.M. organized a committee to be known as the "Advisory Committee on Radioactive Mineral Exploration." This committee is jointly sponsored by the three societies above named.

The following statement was drawn up at the Denver meeting:

1. *Urgency for expanded exploration for radioactive minerals in the United States.*—In view of the increasing importance of radioactive minerals, and in particular of uranium ores, as a source of atomic energy, especially for purposes of national defense, it is urgent that no opportunity be overlooked nor neglected for widespread alertness for evidences of such minerals. Not only is there need for discovering more occurrences of these minerals, but also there is need for more information on their distribution in areas where they are already known to be present.

2. *Coincidence of areas explored for petroleum and areas prospective for uranium ores.*—It so happens that in many regions where oil and gas are sought, ores of uranium may occur. This is especially true of extensive areas in the Rocky Mountain Province and in the western part of the Central Plains Province. There are many deposits of carnotite (a common uranium ore) in the Plateau Province of southeastern Utah and the adjoining corners of Colorado, New Mexico, and Arizona, and recently deposits of uranium minerals have been found in the Powder River Basin in Wyoming. In these same areas, and in many others where uranium ores *may* occur, exploration for petroleum is being carried on aggressively by numerous companies. Therefore, it is suggested that these companies be encouraged to take steps to combine with their petroleum exploration a moderate effort at exploration for radioactive minerals.

3. *Advisory Committee on Radioactive Mineral Exploration.*—Within the membership of the American Association of Petroleum Geologists (A.A.P.G.), the Society of Exploration Geophysicists (S.E.G.), and the Society of Economic Paleontologists and Mineralogists (S.E.P.M.), a committee has been organized, to be known as the Advisory Committee on Radioactive Mineral Exploration.

4. *Functions and policies of the committee.*—This committee, as its name implies, will serve only in an advisory capacity. Its primary functions are:

a. To invite those who may be inclined or interested, to investigate the feasibility of their carrying on exploration for radioactive minerals along with their petroleum exploratory efforts;

b. To give advice as to how and where such exploration for radioactive minerals may be conducted, if desired;

c. To advise where information can be obtained concerning the search for radioactive materials;

d. To endeavor to keep abreast of what is going on in this search for radioactive materials; and

e. To encourage the preparation and presentation of papers on the subject of exploring for useful radioactive minerals.

This committee will concern itself with over-all encouragement of participation of the oil and gas industry in exploration for radioactive minerals and will deal with the broad aspects and policies of such a relationship. It will not be too much concerned with detailed techniques, problems of instrumentation, methods, and processes for detailed surveys, nor with any of the technical aspects of the program which may better be handled by specialists. In no way will it suggest unified cooperation, or cooperative procedure, between organizations for the conduct of radioactive mineral exploration. Its whole objective is to stimulate an interest in the search for radioactive minerals, occurring within feasible mining depths, when and where petroleum exploration is in progress.

5. *Suggestions regarding radioactive mineral exploration.*—The oil companies, consulting firms, and others engaged in petro-

leum exploration can function in exploring for radioactive minerals

(a) by observations with Geiger counter on outcrops where surface mapping is in progress;

(b) by holding out, for special study, those gamma-ray logs which reveal "kicks" stronger than the normal "kicks" known to be associated with the Chattanooga shale or similar highly radioactive shales;

(c) by Geiger-counter or scintillation-counter examination of cuttings from seismic shot holes; and

(d) by similar examination of the cuttings from approximately the upper 500 feet of holes drilled for oil or gas or drilled as exploratory core holes, "slim holes," or "stratigraphic test holes."

(A few remarks may be made here on paragraphs (b), (c), and (d) under 5. When gamma-ray logs show abnormally high "kicks," they may be indicating the presence of radioactive ores at depths too great for exploitation. Such logs may be of value either (1) where they reveal high radioactivity in formations known to be highly radioactive at or near their outcrop, because this suggests wide distribution of such radioactivity, or (2) where by revealing high radioactivity at considerable depths, they suggest that search should be made for indications of similar high radioactivity in the same formations at or near the outcrop of these formations.

Under present prices and conditions, 500 feet is probably as deep as uranium mineral can be profitably mined; hence, the mention of 500 feet in 5(d).)

6. *Utilization of evidences of radioactive minerals.*—If and when evidences of possible economic radioactive minerals is found, the discoverer is free to determine his own course of action. If desired, he could investigate the possibility of mining on his own account; or he could sell his rights, probably on a royalty basis, to some outside mining concern.

7. *Conclusion.*—On the basis of the foregoing, the committee suggests that those engaged in petroleum exploration carefully consider including, in the course of their normal exploration activities, their own program of prospecting for radioactive minerals.

Additional information can be obtained by writing to the chairman of the committee.

Present membership of the Advisory Committee on Radioactive Mineral Exploration is as follows:

Frederic H. Lahee, Chairman
John Emery Adams
John G. Bartram
Henry C. Cortes
Cecil H. Green
Sigmund Hammer
Gerhard Herzog
Morton T. Higgs
J. Harlan Johnson
A. I. Levorsen
Clarence L. Moody
Gerald H. Westby

The committee will be glad to endeavor to answer questions and give advice within the scope of its functions.

THE NEW MEXICO GEOLOGICAL SOCIETY
announces its
THIRD ANNUAL FIELD CONFERENCE
through the
RIO GRANDE TROUGH
October 3, 4, and 5, 1952

The third annual field conference of the New Mexico Geological Society will be held October 3, 4, and 5, 1952, in the Rio Grande Trough of central New Mexico. Participants will register in Santa Fe the afternoon and evening of Thursday, October 2, and over the weekend will proceed south along the east side of the Sangre de Cristo and Sandia Ranges (with a side trip to Sandia Crest at 10,678 feet elevation); the east side of the Manzanita and Manzano Mountains; Abo Canyon and the north end of Chupadera

Mesa; the Socorro Mountains; and the north end of the Caballo Mountains and the Jornada del Muerto, site of recent wildcat drilling.

Sections of rocks ranging from Precambrian to Recent are wll-exposed in the areas to be visited by the field conference, and correction of the Paleozoic and Mesozoic sections will be emphasized. Side trips will be made Saturday to one of the largest perlite deposits in the United States, operated by the Great Lakes Carbon Corporation; and to the Carthage coal field, both near Socorro. The conference will end Sunday afternoon near Truth or Consequences.

A guidebook is being prepared under the editorship of Dr. Charles B. Read, of the U. S. Geological Survey, which will contain articles on the structure, landforms, and Paleozoic and Mesozoic stratigraphy of the ranges bordering the Rio Grande Trough. Detailed road logs, and maps and sections pertinent to the field conference route will also be included in the guidebook.

Inquiries for further details on the trip should be addressed to the New Mexico Geological Society, P. O. Box 27, Campus Station, Socorro, New Mexico.

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To place your order, subject to delivery in September 1952, or for further details please write the address below.

James D. McLean, Jr., P.O. Box 916, Alexandria, Virginia, U.S.A.

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